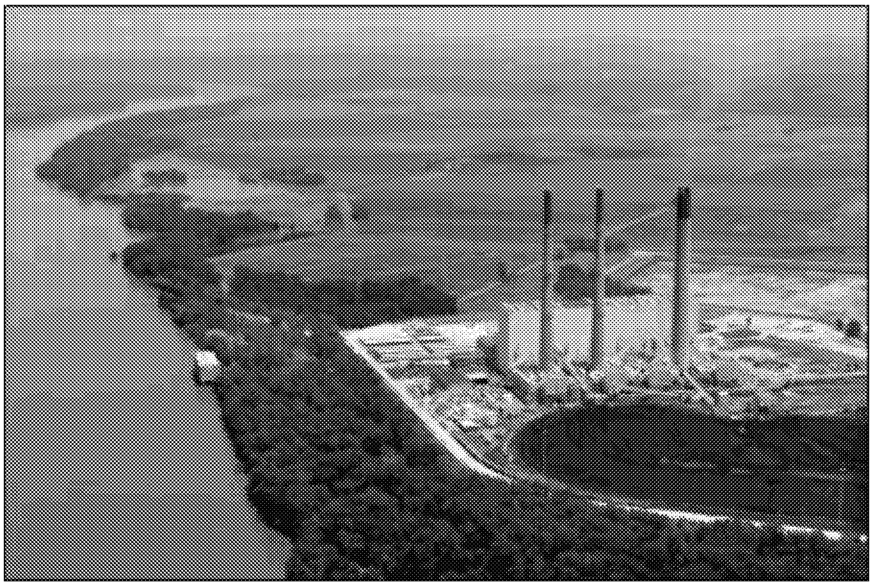
AMEREN MISSOURI LABADIE ENERGY CENTER
CLEAN WATER ACT § 316(b)

EVALUATION TO SUPPORT 40 CFR 122.21(r)



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LIST OF ABBREVIATIONS AND ACRONYMS

AACE	Association for the Advancement of Cost Engineering
AADT	Average Annual Daily Traffic
AC	Alternating Current
AIF	Actual Intake Flow
AOI	Area of Influence
AOQL	Average Outgoing Quality Limit
BOP	Balance of Plant
B&M	Burns & McDonnell
B&V	Black & Veatch
BFS	Benthic Fishes Study\
BPJ	Best Professional Judgement
BTA	Best Technology Available
CAA	Clean Air Act
CCRS	Closed-Cycle Recirculation System
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CO_2	Carbon Dioxide
COC	Cycles of Concentration
CPI	Consumer Price Index
CPUE	Catch per Unit Effort
CSP	Continuous Sampling Plan
CWA	Clean Water Act
CWIS	Cooling Water Intake System
CWS	Cooling Water System
dB	Decibels
dBA	A-weighted Decibels
DC	Direct Current
DIF	Design Intake Flow
DLWL	Design Low Water Level
DO	Dissolved Oxygen
El	Elevation

EIS	Environmental Impact Statement
EMAP-GRE	Environmental Monitoring and Assessment Program for Great River Ecosystems
EPRI	Electric Power Research Institute
EPSM	Environmental Policy Simulation Model
ESA	Endangered Species Act
EY	Equivalent Yield
EYM	Equivalent Yield Model
FEMA	Federal Emergency Management Agency
FIRM	Floodplain Insurance Rate Map
fps	Feet per second
GPD	Gallons per Day
gpm	Gallons per Minute
H-D	Hester-Dendy
HP	Horse-Power
HUD	U.S. Department of Housing and Urban Development
HZI	Hydraulic Zone of Influence
IM	Impingement Mortality
INHS	Illinois Natural History Survey
in	inches
km	Kilometers
kW	Kilowatts
L_{dn}	Day-Night Sound Level
LAR	Larvae of indistinguishable stages of development
lbs	Pounds
LEC	Labadie Energy Center
LMOR	Lower Missouri River
MAF	Million Acre Feet
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
mg/l	Milligrams per liter
MISO	Midcontinent independent system operator
mm	Millimeters
MMBTU/hr	Million British Thermal Units Per Hour

MONHP	Missouri Natural Heritage Program
MSL	Mean Sea Level
Mt/yr	Metric Tons per Year
MRRP	Missouri River Recovery Management Plan
MW	Megawatts
MWL	Mean Water Level
NAVD	North American Vertical Datum
NE	Nebraska
NO2	Nitrite
NO3	Nitrate
NO_x	Nitrogen Oxides
NPDES	National Pollution Discharge Elimination System
NPV	Net Present Value
NRC	Nuclear Regulatory Commission
NTU	Nephelometric Turbidity Units
NWI	National Wetland Inventory
O&M	Operations and Matinenance
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated biphenyls
PFM	Production Foregone Model
PM	Particulate Matter
PM_{10}	Particulate Matter Less Than 10 Microns in Diameter
$PM_{2.5}$	Particulate Matter Less Than 2.5 Microns in Diameter
PSCAP	Pallid Sturgeon Conservation Augmentation Program
PSD	Prevention of Significant Deterioration
PSPAP	Pallid Sturgeon Population Assessment Program
psig	Pounds per Square Inch Gage
PYSL	Post-Yolk Sac Larvae
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RM	River Mile
SAV	Submerged Aquatic Vegetation
SOPs	Standard Operating Procedures

SO_2	Sulfur Dioxide
STPD	Short Tons per Day
TAEB	Total Annual Economic Benefit
T&E	Threatened and Endangered
TDS	Total Dissolved Solids
TL	Total Length
tpy	Tons Per Year
TWS	Traveling Water Screens
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VFD	Variable Frequency Drives
WIMS	Missouri Well Information Management System
Wood	Wood Environmental and Infrastructure Solutions, Inc.
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant
YOY	Young of Year
YSL	Yolk-Sac Larvae
μm	micrometer

1. INTRODUCTION AND EXECUTIVE OVERVIEW

On August 15, 2014, the U.S. Environmental Protection Agency (USEPA) issued final regulations under the Clean Water Act (CWA) (the "§ 316(b) Rule") for existing cooling water intakes. The Rule applies to all existing power generating facilities and existing manufacturing and industrial facilities that withdraw more than 2 million gallons per day (MGD) of water from waters of the United States and use at least 25 percent exclusively for cooling purposes. Under the CWA and as part of a National Pollutant Discharge Elimination System (NPDES) renewal application, the applicant must demonstrate that the location, design, construction and capacity of its cooling water intake structure (CWIS) reflects the Best Technology Available (BTA) for minimizing adverse environmental impact. The primary impacts of concern under § 316(b) are entrainment of smaller aquatic organisms into the cooling water system and impingement of larger organisms onto debris screens within the cooling water intake.

1.1 STUDY AREA

The Labadie Energy Center (LEC) is a coal-fired steam electric generating station located on the southern shore of the Lower Missouri River (LMOR) at River Mile (RM) 57.5 in Labadie, Missouri. The facility is located along a low- lying floodplain area of the river generally known as Labadie Bottoms (Figure 1-1), which is approximately 2 miles wide and enclosed by steep bluffs that rise up to several hundred feet above the floodplain (USGS 2017a; USGS 2017b). Labadie Bottoms is protected from moderate flooding by a non-federal, agricultural levee with a crest elevation (El.) of about 480 feet above mean seal level (MSL) (Ameren 2009). A large portion of Labadie Bottoms is situated within the Federal Emergency Management Agency (FEMA) 100-year regulatory floodplain (FEMA 1984), and flooding of the general area has occurred on numerous occasions. The layout of the LEC is shown in Figure 1-2.

The LEC is located within the channelized reach of the LMOR, which extends 735 miles downstream from Sioux City, Iowa to the confluence with the Mississippi River near St. Louis. The river in this section has been straightened, deepened, and narrowed by the construction of revetments and dikes, and by dredging to maintain a 300-foot wide navigation channel that is at least 9 feet deep (NRC 2002). Near the LEC, the river has been reinforced with rip-rap and revetments, and the bottom drops sharply because the channel closely approaches the south bank. Average depth is approximately 16 feet in the vicinity of the LEC CWIS and discharge canal (UEC 1976). Rock pile dikes extend into the river on the north bank and downstream from the plant on the south bank. Sandy beaches are exposed at low water levels. The river currents past the facility are swift, with velocities estimated typically between 2.6 and 4.8 feet per second. There is no rooted vegetation and the substrate consists of rock, stone or gravel in areas of current, and silt or clay in depositional areas.

1.2 FACILITY AND INTAKE STRUCTURE DESCRIPTION

There are four generating units at the LEC with a total generating capacity of 2,580 megawatts (MW). Each of these units uses a once-through cooling water system to remove waste heat. At a normal water El. of 455 ft, the design intake flow (DIF) of the LEC is currently 1,448 MGD or 2,240 cubic feet per second (cfs). Withdrawal and discharge of water from the Missouri River is authorized by NPDES Permit Number MO-0004812 issued by the Missouri Department of Natural Resources (MDNR).

Each of the LEC's units withdraws circulating water through two separate pump bays. Each of the eight bays is about 11 feet wide with an upper and lower intake opening, and is equipped with trash racks, a traveling screen, and a vertical, circulating water pump. Full face

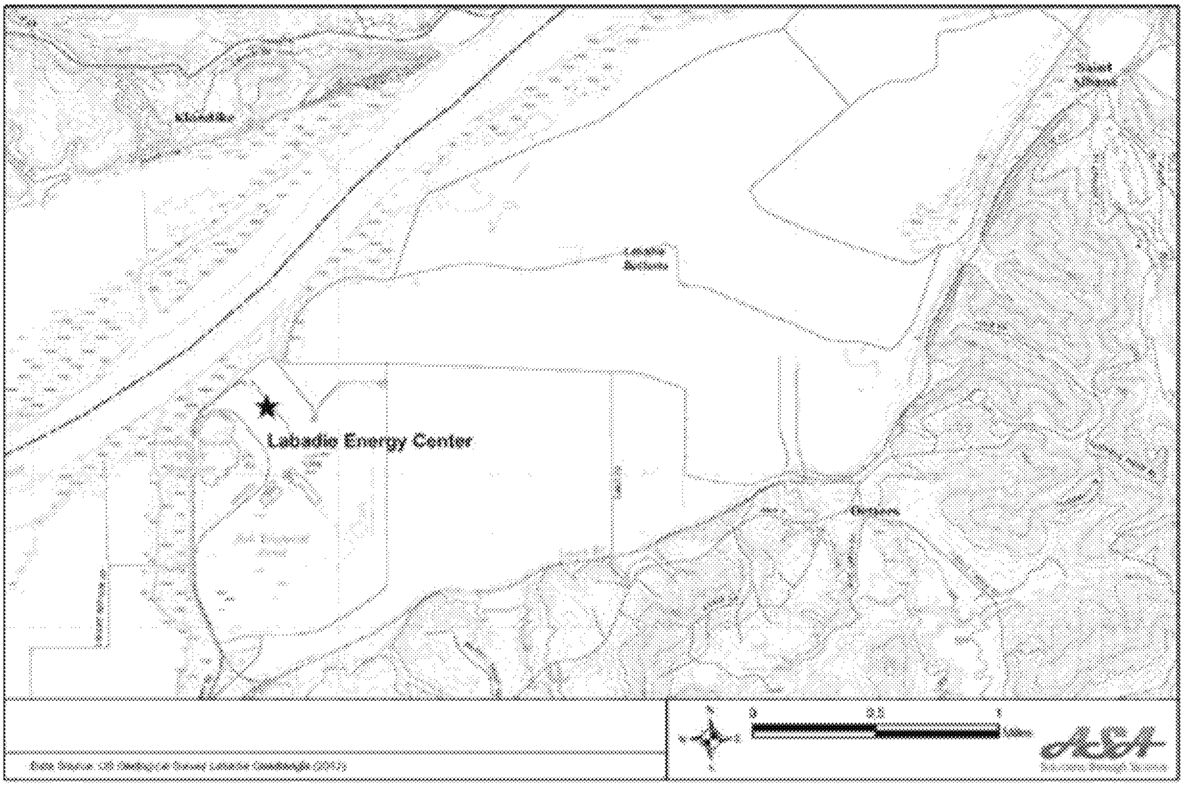

Figure 1-1 USGS Topographic Map of the LEC Area, Franklin, Co., Missouri

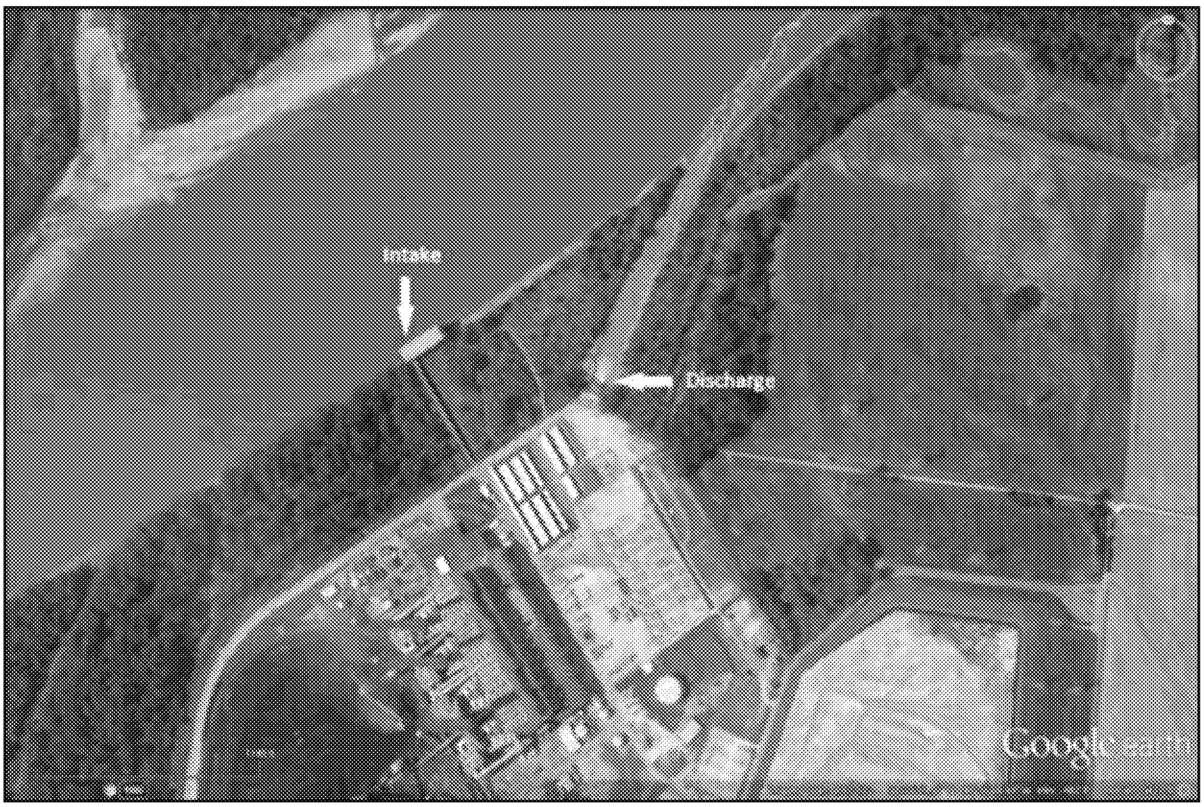

Figure 1-2 LEC - Site Layout.

trash racks are installed in front of the upper and lower intake openings, which have separate stoplog gates and a raking system. The upper intake opening is 10 feet wide by 9 feet high with an invert at El. 440.0 feet. The lower intake opening is 9 feet wide by 7.7 feet high with an invert at El. 430.3 feet with a top deck at El. 494.0 feet.

The steel trash racks are installed vertically and are made of 4-in. x 1/2-in. bars spaced 3 inches (in.) on- center (clear opening of 2.5 in.). Floor splitters and fillets have been installed on the intake bay floor, and baffles are installed just upstream of each pump to reduce pump cavitation. Traveling water screens (TWS) are located about 23 feet downstream of the trash racks and about 10 feet downstream of the stoplog gates. Each screen is 10 feet wide and is constructed of woven wire mesh with 3/8-in. square mesh openings. The distance between the bottom and top sprocket is 66 feet. The traveling screens can operate at either high or low speeds and can be controlled manually or automatically. The screens are automatically operated once every 12 hours at a slow speed of 5 feet/minute for 1.25 revolutions. If the differential head across the screen reaches 8 inches, the screens rotate at the slow speed. If the differential across the screen reaches 12 inches, the screens rotate at a high speed of 20 feet/minute until the differential drops to 4 inches. Screen operation is dictated by river and operational conditions with more frequent operations occurring when there are large amounts of debris or ice present. A high pressure (100-pounds per square inch gauge [psig]) front-wash spray system is used to remove impinged fish and debris from the screens. The wash water flows into a single trough in the screenhouse floor and then transitions into a pipe that returns the fish and debris to the river.

Each bay has a vertical, mixed-flow circulating water pump with impellors located approximately 25 feet downstream of the TWS. The circulating water pumps are each rated for 125,672 gallons per minute (gpm) or 280 cfs at 56 feet of head. At a normal water level of El. 455 feet, the total facility DIF is 1,005,378 gpm (2,240 cfs).

The cooling water is discharged back into the Missouri River approximately 1,500 feet downstream of the intake structure. The heated water is discharged through four, 8-foot diameter pipes (one for each unit) leading to a seal well. The seal well discharges over a weir and into 0.22-mile discharge canal designated as Outfall # 001 (Non-contact Cooling Water). During winter, warm water from the seal pit is rerouted to a re-circulating pipe located between the trash racks and intake openings to prevent ice formation on the trash racks and screens.

The LEC has operated since 1973, and biological sampling at the facility in the LMOR has shown that LEC's operation has had no measurable impact on LMOR. The key reasons for low/no impact is that the LEC withdraws approximately 3 percent of LMOR flow, and the organisms LMOR entrains are dominated by low value and or invasive species. This report provides information about the LEC, its CWIS and operations; LMOR, its organisms distribution and seasonality; assesses various technologies to further reduce impingement mortality and entrainment. The evaluation found that replacing the existing coarse-mesh conventional traveling screens with modified coarse-mesh traveling screens and installing a fish return system may be an appropriate impingement mortality reduction measure. The evaluation also demonstrates that existing design and operational measures is BTA for entrainment compliance.

1.3 REPORT ORGANIZATION

As part of their NPDES permit renewal, existing facilities are required to develop and submit technical reports and assessments as required by 40 CFR 122.21 (r) (2) through (8). So as to facilitate the review of such material, this submittal is organized as follows:

- Chapter One - Introduction and Executive Overview
- Chapter Two - 40 CFR 122.21 (r)(2) - Source Water Physical Data

- Chapter Three – 40 CFR 122.21 (r)(3) - Cooling Water Intake Structure Data
- Chapter Four – 40 CFR 122.21 (r)(4) - Source Water Baseline Biological Characterization
- Chapter Five – 40 CFR 122.21 (r)(5) - Cooling Water System Data
- Chapter Six – 40 CFR 122.21 (r)(6) - Chosen method(s) of Compliance With impingement Mortality Standard
- Chapter Seven – 40 CFR 122.21 (r)(7) - Entrainment Performance Studies
- Chapter Eight - 40 CFR 122.21 (r)(8) - Operational Status
- Chapter Nine – 40 CFR 122.21 (r)(9) - Entrainment Characterization Study
- Chapter Ten – 40 CFR 122.21 (r)(10) - Comprehensive Technical Feasibility and Cost Evaluation Study
- Chapter Eleven – 40 CFR 122.21 (r)(11) - Benefits Valuation Study
- Chapter Twelve – 40 CFR 122.21 (r)(12) - Non-Water Quality Environmental and Other Impacts Study
- Chapter Thirteen – 40 CFR 122.21 (r)(13) – Peer Review

1.4 EXECUTIVE OVERVIEW

Existing facilities with a DIF greater than 2 MGD are required to submit a set of documents with their NPDES application for renewal to establish compliance with the Rule, 40 CFR 122.21(r)(2) through (8):

- § 122.21(r)(2) – Source Water Physical Data;
- § 122.21(r)(3) – Cooling Water Intake Structure (CWIS) Data;
- § 122.21(r)(4) – Source Water Baseline Biological Characterization Data;
- § 122.21(r)(5) – Cooling Water System Data;
- § 122.21(r)(6) – Chosen Method of Compliance with the Impingement Mortality Standard;
- § 122.21(r)(7) – Entrainment Performance Studies;
- § 122.21(r)(8) – Operational Status;

Facilities such as the LEC, with an actual intake flow (AIF) of greater than 125 MGD, are required to submit five additional documents to establish compliance with 40 CFR 122.21(r)(9) through (13):

- § 122.21(r)(9) – Entrainment Characterization Study;
- § 122.21(r)(10) – Feasibility and Cost Study;
- § 122.21(r)(11) – Benefits Valuation Study;
- § 122.21(r)(12) – Environmental and Other Impacts; and,
- § 122.21(r)(13) – Peer Review of (r)(10), (r)(11), and (r)(12).

The § 316(b) Rule requires each affected facility to develop and submit to the NPDES Director (i.e., MDNR) specific submittals and supporting information to address compliance with the Rule's performance standards. Pursuant to Special Condition 19 of the LEC's NPDES permit (MO-

0004812) Ameren must submit its Section 316(b) application six months before the permit expiration date of 31 July 2020.

This Executive Overview summarizes the principal conclusions from the attached technical assessment reports and Ameren's proposed compliance approach for meeting both impingement mortality (IM) BTA and entrainment BTA under the final § 316(b) Rule. The State regulatory requirements presented at § 25.98(f) of the Rule were used to guide the organization of this report and to aid MDNR in making its BTA determination for the LEC.

The principal observations from the various reports are summarized below:

- In contrast to studies from more than a decade ago, Asian Carps now dominate (>85%) entrainment samples collected at the CWIS and in-river ichthyoplankton samples collected near the LEC and appear to be well established and reproducing near the LEC.
- Pallid sturgeon and shovel nose sturgeon are present in the LMOR with the majority of individuals collected upstream of the LEC and near the confluences of the Gasconade and Osage Rivers. No pallid sturgeon have been collected in samples in the vicinity of the LEC and there is no pallid sturgeon designated critical habitat within the LMOR.
- No threatened or endangered species of freshwater mussels were collected during recent or historical sampling conducted in the vicinity of the LEC.
- Peak entrainment generally occurs between mid-May and mid-June.
- Invasive, non-native Asian carps, including silver carp, bighead carp, and grass carp, combined to represent approximately 8.3 billion of the 9.8 billion fish eggs and larvae (85 percent) estimated to have been entrained at the LEC during 2015 and 2016.
- Excluding Asian carps, recreational game fish represented less than one percent of the total entrainment estimate.
- Coarse-mesh modified TWS were found to be the more appropriate impingement mortality reduction technology at the LEC. This selection would be finalized by Ameren following the entrainment BTA selection by the Director. The screen installation plan would be submitted to MDNR at that time.
- While cooling towers and various fine-mesh screen technologies could potentially reduce entrainment, such technologies pose significant challenges to the operation of the LEC. Additionally, none of the entrainment reduction technology costs are justified by their benefits.

A summary of the evaluation of the primary factors considered for the IM and entrainment compliance options at the LEC is presented in Tables 1-1 and 1-2, respectively.

Table 1-1. Summary of IM Compliance Option Evaluation

Impingement Reduction Technology Evaluated	Specific Technology Considered	Feasibility	Proven Efficacy for Reducing Impingement Mortality	Potential to Reduce Entrainment	Monitoring Requirements and Qualitative O&M effort	Budgetary Cost Estimates	Alternative for Consideration at the LEC
Mechanical Draft Cooling Towers	Mechanical draft cooling tower with makeup water from Ranney wells	Proven Technology; Major Installation/Operational Issues Note: Per EPA - appropriate only if alternative is also required for entrainment reduction. EPA did not intend for facilities to retrofit to a closed-cycle system to satisfy IM compliance alone.	Yes	Yes	Additional O&M due to additional mechanical equipment; no additional monitoring	High capital and O&M costs ~$432 M capital $15M annual O&M	Reject Not required for IM compliance alone at once-through facilities High cost and long implementation timeline relative to other alternatives. Significant Permitting Issues.
Design or Actual Through-Screen Velocity of 0.5 feet per second ***See Note 1**	Expansion of intake structure to reduce intake velocity	Known technology but feasibility at the LEC uncertain Physical expansion would necessitate greater than 3-fold expansion of the intake (preliminary calculations indicate approximately 25 coarse-mesh 12-foot traveling water screens needed) Cooling water flow/hydraulic balance between screens and pumps may be difficult to achieve; construction and permitting challenges associated with riparian zones and in-river habitats	Yes Due to velocity < 0.5 fps	Minimal Late-stage larvae may be able to swim away due to velocity < 0.5 fps	Additional O&M due to additional mechanical equipment; no additional monitoring	~$75-$100 M Capital ~$0.5 to $0.75 M annual O&M	Reject Higher cost relative to other alternatives. Likely hydraulic imbalances. Significant Permitting Issues.
	Installation of Wedge wire screens	Not Feasible – geographic limitations; permitting challenges Not practical due to safety concerns; proximity of river channel and potential for navigation interference with barge traffic; high potential for debris loading/fouling; construction and permitting challenges with in-river installation	Not evaluated in detail; Technology determined to be not feasible at the LEC				Reject

Impingement Reduction Technology Evaluated	Specific Technology Considered	Feasibility	Proven Efficacy for Reducing Impingement Mortality	Potential to Reduce Entrainment	Monitoring Requirements and Qualitative O&M effort	Budgetary Cost Estimates	Alternative for Consideration at the LEC
Install a Modified Traveling Screen (BTA)	Replace eight existing conventional traveling water screens with modified coarse-mesh traveling screens with fish lifting buckets; low-pressure wash for organisms and high-pressure wash for debris; continuous or near-continuous screen rotation. Install fish return system.	Yes	Yes	No	2-year optimization study	$14 - $16 M ~$0.25 to $0.5 M annual O&M Two screens to be piloted before replacing others during three consecutive outages	Yes – Proposed as BTA for impingement reduction
	Replace eight existing conventional traveling water screens with 2-mm dual flow modified traveling water screens, with fish lifting buckets; low-pressure wash for organisms and high-pressure wash for debris; continuous or near-continuous rotation. Install fish return system.	Yes Some civil modifications to intake structure to accommodate dual flow screens (reconfiguration of intake bays). Uncertainty in the ability to successfully install and operate 2-mm mesh dual-flow traveling screens.	Inconclusive feasibility – additional studies needed to assess velocity profile on screens. Higher velocities could result in lower efficacy.	Possible, but inconclusive feasibility	2-year optimization study	~ $20 M Capital ~ $0.3 M annual O&M Two screens to be piloted before replacing others during three consecutive outages	Reject Longer implementation timeline due to civil modifications and inconclusive feasibility. Higher cost relative to thru-flow coarse-mesh option.
	Expand existing intake by 6 additional bays; install in all 14 intake bays modified 0.5-mm mesh traveling screens with fish lifting buckets; low-pressure wash for organisms and high-pressure wash for debris; continuous or near-continuous screen rotation. Install fish return system.	Known technology but inconclusive feasibility as intake would require significant expansion that could result in additional significant engineering, land conversion, riparian zone and in-river habitat alteration, and environmental permitting.	Uncertain – few installations in the country, their focus was primarily entrainment reduction	Yes	2-year optimization study	$48 M Capital $0.5 M annual O&M	Reject Higher cost relative to other alternatives. Long intake/plant outage. Operational uncertainties. Longer implementation timeline. Significant Permitting Challenges
Combination of Technologies, Practices & Operational Measures	Potential Measures: Water withdrawal reduction, wedge-wire screens, barrier nets, behavior deterrents	None identified as potentially feasible given site-specific conditions Operational measures not feasible as LEC operates as baseload units; Water withdrawal reduction not possible at the LEC while maintaining generation capacity, other options are not practical at the scale needed for the LEC or are not proven effective at reducing impingement mortality	N/A	N/A	N/A	Not evaluated	Reject

Impingement Reduction Technology Evaluated	Specific Technology Considered	Feasibility	Proven Efficacy for Reducing Impingement Mortality	Potential to Reduce Entrainment	Monitoring Requirements and Qualitative O&M effort	Budgetary Cost Estimates	Alternative for Consideration at the LEC
Achieve the Specified Impingement Mortality Performance Standard (annual mortality 24% for nonfragile species)	Potential future innovative technology – none currently identified	N/A	N/A .	N/A	Unknown Ongoing performance monitoring and must meet quantitative performance standard. Inability to meet performance standard results in reportable non-compliance	N/A	Reject

Note 1: Wedge-wire screens were evaluated in the (r)(10) report.

Note: De Minimis rate of impingement is excluded due to IM exceeding De Minimis levels

Note: Low capacity utilization rate excluded due to LEC operating regime does not meet the low capacity utilization rate standard

Note: Offshore velocity cap is excluded due to no velocity cap installed before Oct. 14, 2014.

Table 1-2 Summary of Entrainment Compliance Option Evaluation

Entrainment Reduction Technology Evaluated[1]	May Factors			Must Factors						Conclusion
	Reliability Impacts	Water Consumption Impacts	Alternate Water/Water Reuse	Organisms Entrained[2]	Particulate Emissions Impacts	Land Availability	Remaining Plant Life[3]	Social Costs	Social Benefits	
Mechanical Draft Cooling Towers	No impact on regional/local grid reliability	Current water consumption impacts are negligible Evaporation increased by approximately 31,000 gpm under full load; water would be replenished with groundwater instead of surface water	Ranney wells could supply make-up water; geology and aquifer would need to be evaluated to determine if yield is feasible	No threatened or endangered (T&E) species 85% Asian carps <1% recreational game fish (after excluding Asian carp) Could result in 95 to 100 % reduction in entrainment	Marginal increase in PM emissions from cooling towers	Available, although significant fill needed	Analysis based on 30-year expected lifespan of plant High capital and operating costs could impact remaining life of asset	Negative $592 M	Minimal ~$0.1 to $0.2 M	Social costs not justified by social benefits
Cooling Pond	Not evaluated in detail since there is insufficient land onsite to construct appropriately sized pond					No (Would require 4,200 acres)	Not evaluated in detail since there is insufficient land onsite to construct appropriately sized pond			Excluded
2-mm Dual Flow Screens in Existing Intake	No impact on regional/local grid reliability	Current water consumption impacts are negligible No impact from fine-mesh screens on consumptive use	N/A	No T&E species 85% Asian carps <1% recreational game fish (after excluding Asian carps) Could result in minimal reduction in entrainment.	None	N/A	Analysis based on 30-year expected lifespan of plant Installation of fine mesh screen has insignificant impact on remaining life of plant	Negative $16 M	Negligible <$0.1 M	Social costs not justified by social benefits
0.5 mm Modified Traveling Screens in Expanded Intake	No impact on regional/local grid reliability	Current water consumption impacts are negligible No impact from fine-mesh screens expected on consumptive use of water	N/A	No T&E species 85% Asian carps <1% recreational game fish (after excluding Asian carps) Could result in moderate reduction in entrainment.	None	N/A.	Analysis based on 30-year expected lifespan of plant Negligible/marginal impact on remaining life if reliability becomes an issue.	Negative $40 M	Negligible <$0.1 M	Social costs not justified by social benefits

Entrainment Reduction Technology Evaluated[1]	May Factors			Must Factors						Conclusion
	Reliability Impacts	Water Consumption Impacts	Alternate Water/Water Reuse	Organisms Entrained[2]	Particulate Emissions Impacts	Land Availability	Remaining Plant Life[3]	Social Costs	Social Benefits	
Fine Mesh Screens – Wedge-Wire Screens	No impact on regional/local grid reliability.	Current water consumption impacts are negligible. No impact from fine-mesh screens expected on consumptive use of water	N/A	No T&E species 85% Asian carps <1% recreational game fish (after excluding Asian carps) Could result in reduction in entrainment.	None	N/A	Analysis based on 30-year expected lifespan of plant Negligible/marginal impact on remaining life if reliability becomes an issue.	N/A	N/A	Excluded Geographic limitations; permitting challenges

1 = Water reuse from groundwater wells and water reuse from greywater discharges are excluded due to insufficient supply of water

2= Entrainment numbers based on 2015-2016 sample collection

3 = Net present value calculations are based on an assumed 30-year remaining life for the LEC. The actual retirement dates could be considerably shorter as Ameren Missouri's 2017 Integrated Resource Plan projects two unit retirements in 2037 and the remaining two units in 2043. The shorter actual life would result in the same annual social benefits, but significantly higher annualized social costs (capital costs annualized over a shorter period of time), with the net impact being still lower social benefit to social cost ratio.

4 = MAY factors described at 40 CFR 125.98(f)(3) also include entrainment impacts on the waterbody; thermal discharge impacts; and credit for reductions in flow. Since none of the technologies evaluated would have entrainment impact on the source waterbody or thermal discharge impacts and the LEC is not claiming any reductions in flow, these three MAY factors were not included in the above table.

1.4.1 Summary of the Plant and its Surroundings

1.4.1.1 Plant Layout and Operation – 40 CFR 122.21(R)(3), (5), & (8)

The LEC is located on the southern shore (right descending bank) of the LMOR in Labadie, Missouri, approximately 35 miles west of St. Louis.

Cooling water is withdrawn through a CWIS that is located along the shoreline of the river and consists of four cells, one for each unit. Each cell is comprised of two bays (8 in. total) with each bay consisting of a trash rack, TWS, and circulating water pump. TWS are 10 feet wide and are constructed of woven wire mesh with 3/8-in. square mesh openings. The screens are operated automatically every 12 hours or more frequently based on measurements of differential head across the screens. A front-wash spray system removes impinged fish and debris from the screens into a single trough that transitions into a pipe that returns the fish and debris to the river.

When operating at its DIF, the LEC withdraws an average monthly maximum of 3.7 percent of the LMOR flow. This maximum withdrawal occurs in February; outside the principal entrainment period. The average annual actual intake flow (AIF) at the LEC ranged from 85 to 94 percent of its DIF during the five-year period from 2014 through 2018. AIF varies throughout the year due to both generation and ambient conditions. Based on AIF during the same five-year period, the plant withdrew a maximum of 3 percent of the monthly LMOR flow. Minimum percent withdrawal occurs in spring and early summer (April – July), during the peak entrainment period.

There have been no major system upgrades or changes during the last 15 years at the LEC with respect to intake flows, and there are no plans for shutting down the plant or for adding any new units in the next five years. Therefore, there should not be any major fluctuations, reductions, or increases in flow occurring during the foreseeable future.

More detailed information on CWIS layout, operation, capacity utilization, generation, intake flow, withdrawal rate, percent of LMOR flow withdrawn, and a water balance diagram, may be found in the *§ 122.21(r)(3) Cooling Water Intake Structure Data, § 122.21(r)(5) Cooling Water System Data*, and *§ 122.21(r)(8) Operational Status* submittal reports.

1.4.1.2 Source Waterbody and Biological Community – 40 CFR 122.21(R)(2), (4), & (7)

The Missouri River is a major river system in the U.S. with a 529,350 square mile drainage basin as it flows 2,341 miles from its headwaters in Montana to its confluence with the Mississippi River at St. Louis, Missouri. Dam construction and channelization along the mainstem has fragmented the river into four types of ecological units: a free-flowing reach upstream of the reservoirs, the reservoirs, remnant floodplains between the reservoirs, and a channelized reach below the most downstream reservoir (NRC 2002). The LEC is located within the channelized reach of the LMOR, where the river has been straightened, deepened, and narrowed by the construction of revetments and dikes and by dredging. The main channel runs very close to the LEC CWIS due to its location on an outside bend. This area of the river is characterized by swift currents and a shifting substratum, which is not preferred fish habitat (MDNR 2017).

A number of fish survey programs have conducted sampling within the LMOR which provide a wealth of information to describe the fish community in the vicinity of LEC. These include past and recent in-river biomonitoring studies conducted in the vicinity of the LEC, the Pallid Sturgeon Population Assessment Project (PSPAP) monitoring program, and the Benthic Fishes Study (BFS). Furthermore, recent impingement abundance monitoring was conducted at the LEC CWIS during 2005 – 2006 (ASA and Alden 2008) and a two-year entrainment characterization study was conducted during 2015 and 2016. Detailed information regarding the methodologies employed for each survey program is described in the *§ 122.21(r)(4) Source Water Baseline Biological Characterization Data* report.

There were 104 species and three hybrids collected from the LMOR in the reviewed studies. More than half of all taxa collected belonged to the carp and minnow (37 species), sucker (13 species), and sunfish (12 species) families. Catfishes, including blue catfish (*Ictalurus furcatus*), channel catfish (*Ictalurus punctatus*), and flathead catfish (*Pylodictis olivaris*); freshwater drum (*Aplodinotus grunniens*); gizzard shad (*Dorosoma cepedianum*); goldeye (*Hiodon alosoides*); longnose gar (*Lepisosteus osseus*); red shiner (*Cyprinella lutrensis*); and river carpsucker (*Carpiodes carpio*) frequently were among the most numerous species collected during sampling conducted in the river. These species, along with shovelnose sturgeon (*Scaphirhynchus platorynchus*), accounted for greater than 95 percent of the total number of fish and biomass collected during the 2005 - 2006 impingement sampling.

In contrast, recent ichthyoplankton samples collected near the LEC and at its CWIS were dominated by species of invasive, nonnative Asian carps, including silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), and grass carp (*Ctenopharyngodon idella*). These taxa comprised approximately 85 percent of estimated entrainment during the 2015 – 2016 entrainment characterization study as well as 85 percent of the 2017 - 2018 biomonitoring catch made during in-river ichthyoplankton sampling conducted near the LEC. Generally regarded as nuisance species, Asian carps have become abundant in many river systems in recent decades, including the LMOR. These species are now well established and reproducing near the LEC. Results of the 2015 – 2016 entrainment characterization study are summarized in further detail in Section 1.4.3.1 of this Executive Overview, as well as in the *§ 122.21(r)(9) Entrainment Characterization Study* submittal report.

Two federally-listed threatened or endangered (T&E) species, the pallid sturgeon (*Scaphirhyncus albus*) and shovelnose sturgeon, are present in the LMOR based on the reviewed studies. The federal and Missouri state-listed endangered pallid sturgeon was only collected during sampling conducted for the PSPAP, which was designed to estimate the population size, structure, and distribution of the species. The majority of individuals collected in the LMOR were caught near the confluences with the Osage River at RM 130.2 and the Gasconade River at RM 105 well upstream of the LEC. None have been identified during any recent or past collections made in the vicinity of the LEC or at the CWIS. Furthermore, there is no pallid sturgeon designated critical habitat within the LMOR.

The shovelnose sturgeon is listed as federally threatened due to its similarity in appearance to pallid sturgeon. However, the species is numerous in the river and continues to be fished recreationally. A total of eleven shovelnose sturgeon were collected during 2005 – 2006 impingement monitoring conducted at the LEC.

In addition to pallid sturgeon, two Missouri state-listed endangered species were collected in the LMOR according to the reviewed studies, the lake sturgeon (*Acipenser fulvescens*) and the flathead chub (*Platygobio gracilis*). Lake sturgeon (9 individuals), skipjack herring (10 individuals), and sturgeon chub (1 individual) were collected from the LEC CWIS during 2005 – 2006 impingement monitoring. However, the lake sturgeon were hatchery-reared fish that were stocked upstream of the LEC by the Missouri Department of Conservation (MDC) days prior to being collected at the LEC during one sampling event. Thus, their collection likely was not representative of actual rates of impingement of the species at the LEC CWIS.

Twenty species of freshwater mussels were identified in surveys conducted along the entire length of the channelized portion of the LMOR as well as the reach immediately below Gavins Point Dam. While one recently dead specimen of the federal and Missouri state-listed endangered scaleshell (*Leptodea leptodon*) was collected during river surveys in the LMOR in

1990 from Gasconade County, no T&E species of freshwater mussels were collected during recent or historical sampling conducted in the vicinity of the LEC.

More detailed information on the LMOR and the biological community, including hydrology, geomorphology, water quality, fisheries, and freshwater mussel community may be found in the *§ 122.21(r)(2) Source Water Physical Data*, *§ 122.21(r)(4) Source Water Baseline Biological Characterization Data* and *§ 122.21(r)(7) Entrainment Performance Studies* submittal reports.

1.4.2 Impingement Mortality BTA – 40 CFR 122.21(R)(6)

The Rule is prescriptive regarding IM BTA and allows the station to choose one of seven pre-approved options for compliance. These seven options are to be evaluated on a site-specific basis in the *§ 122.21(r)(6)* Study. In accordance with the 40 CFR 125.94(c) Rule, final selection of IM BTA will follow selection of entrainment BTA.

After careful review and evaluation of the seven IM compliance alternatives, Ameren has chosen Compliance Alternative 5 (modified traveling screens and fish return system) as the IM BTA for the LEC.

Assuming the MDNR concurs that existing design and operational measures are BTA for entrainment, impingement BTA compliance will be met by replacing the LEC's existing conventional TWSs with coarse-mesh modified-TWS and a fish return system. Modified-TWS would include the following: smooth-tex coarse-mesh to prevent fish scaling; fish buckets to carry impinged fish up to the fish trough; low-pressure screenwash headers to gently remove and wash fish from the buckets to the fish trough; and high-pressure screenwash headers to remove debris from the screen and transfer to the debris trough. The fish trough would transition into the fish return and route the organisms back to the LMOR. The modified-TWS would be rotated continuously or near-continuously to reduce the amount of time that an organism would remain impinged on the mesh. A two-year optimization study would be conducted following the replacement of all the screens; the study would aim to assess the most beneficial screenwash pressure, screen rotation speed and frequency, evaluate the relative merits of separating or combining the fish and debris troughs, etc.

However, the LEC is also subject to the site-specific entrainment requirements along with additional study requirements set forth in § 122.21(r)(1)(ii)(B). Therefore, consistent with the § 316(b) Rule, the final selection of an IM BTA compliance is deferred until after the MDNR makes the entrainment BTA determination. At that time, Ameren will submit its final chosen method of compliance for impingement mortality reduction BTA, along with its implementation schedule.

1.4.3 Entrainment Mortality Reduction BTA

This section summarizes the studies required by the final § 316(b) Rule relative to a site-specific best professional judgment (BPJ) entrainment BTA selection at the LEC.

The sequence of studies intended to support a BTA determination for the LEC is set forth in Figure 1-3. The workflow includes integration of information on the configuration and operation of the plant, as well as the ecological and social changes likely to arise if alternative cooling water technologies were adopted. The steps involved in assessing social costs, social benefits, and other environmental impacts are outlined along with the peer review process. While information presented under 40 CFR 122.21(r)(2) through (8) often provides useful perspective on the entrainment BTA and will be cited as necessary, this summary focuses on information provided in the following studies prepared under 40 CFR 122.21(r)(9) through (13).

1. The Rule at § 122.21(r)(9) requires a study to collect and present data sufficient to characterize facility entrainment; to describe species that get entrained into the cooling

system, their abundance, seasonality, year to year variability, etc. The results are summarized in the attached Entrainment Characterization Study for the LEC.

2. The Rule at § 122.21(r)(10) requires the evaluation of the feasibility of constructing and operating closed-cycle cooling, fine-mesh (smaller than 2-millimeter (mm) opening), or alternate water sources or reuse of existing water sources, and the cost to the facility and to society.
3. The Rule at § 122.21(r)(11) requires a study be prepared that quantifies biologic and economic benefits of entrainment reductions associated with each alternative deemed feasible at that facility. The attached Benefits Valuation Study evaluates the social benefits of implementing potentially feasible entrainment reduction technologies at the LEC.
4. The Rule at § 122.21(r)(12) requires a study of the non-water quality environmental (and other) impacts for each technological alternative considered in the (r)(10) report. These include changes in facility's energy usage, air emissions, noise, safety, reliability, and water consumption along with a discussion of efforts to mitigate any adverse impacts.
5. In accordance with Rule requirements at § 122.21(r)(13), the § 122.21(r)(10) through (12) studies are to be peer reviewed by third-party professionals approved by MDNR. Ultimately, the peer reviewers are to convey to MDNR via the (r)(13) report if (r)(10), (11), and (12) reports have been prepared with sufficient rigor to facilitate the permit writer to use information and recommendations from those reports when selecting the entrainment BTA measure.

Sections 1.4.3.1, 1.4.3.2, 1.4.3.3, and 1.4.3.4, summarize the information provided in the § 122.21(r)(9), (r)(10), (r)(11), and (r)(12) submittal reports, respectively. Section 1.4.3.5 provides a summary of the peer review process. Section 1.4.4 uses information in § 122.21(r)(9), (r)(10), (r)(11), and (r)(12) to respond to the factors in 125.98(f)(2) and (3) that the Director must and may consider, respectively, when determining the entrainment BTA for the facility.

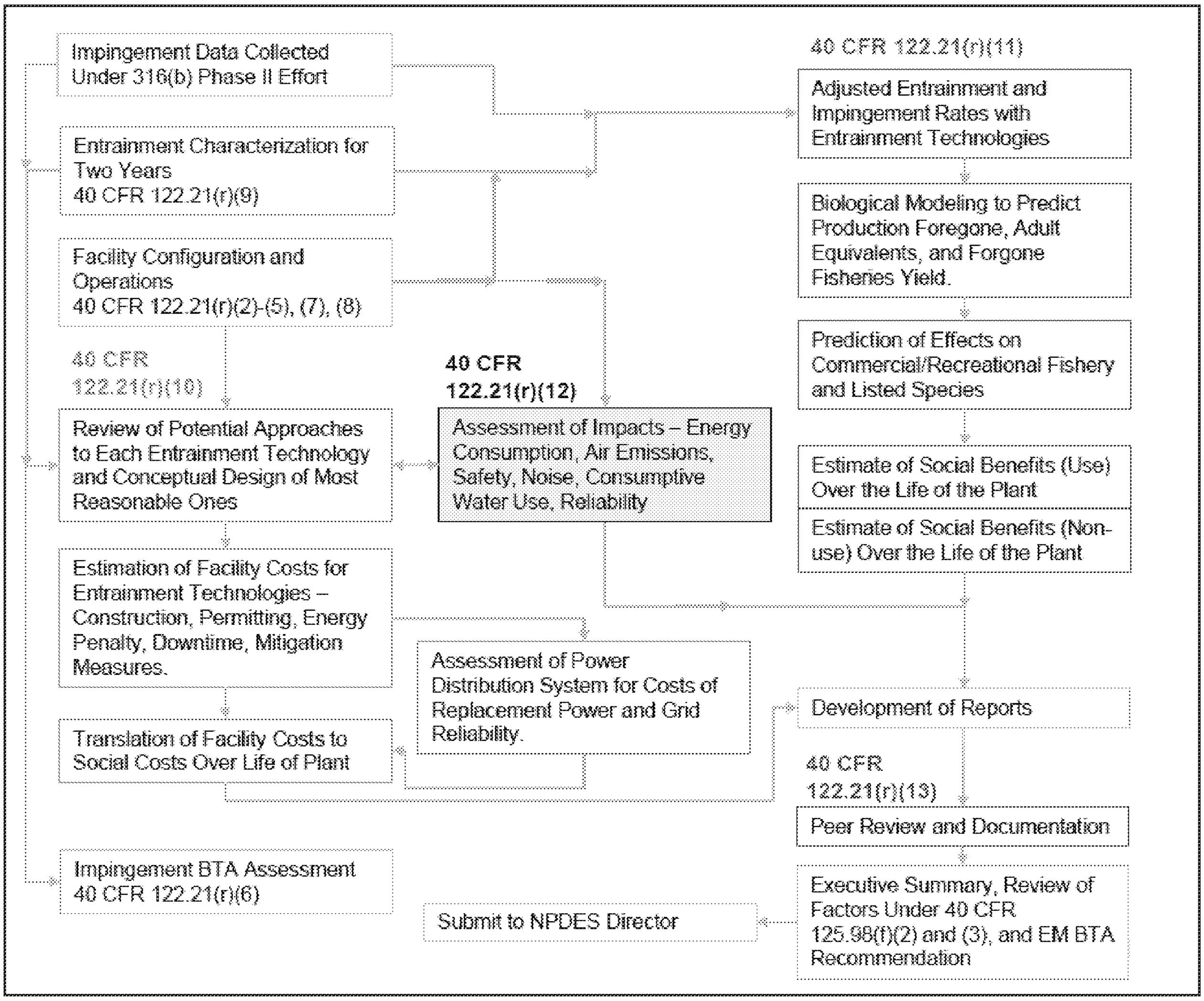

Figure 1-3 Entrainment BTA workflow.

1.4.3.1 Entrainment Characterization Study – 40 CFR 122.21(R)(9)

The LEC conducted a study during 2015 and 2016 to characterize annual, seasonal, and diel variability in entrainment of fishes of all life stages at the plant as specified under the § 122.21(r)(9) requirements. Sampling was performed weekly from March through September (the period of the year when entrainment is most likely to occur). Entrainment sampling was conducted using a pump-and-net barrel sampler equipped with a 335-micrometer (µm) mesh ichthyoplankton net to collect water from the LEC discharge seal well and filter out fish eggs and larvae. Samples were collected approximately every six hours over each 24-hour sampling event.

A total of 70,704 fish eggs, larvae, and entrainable-sized juveniles and adults were collected during 30 sampling events conducted at the LEC during 2015, whereas 49,986 specimens were collected during 31 entrainment sampling events in 2016. Larvae represented 99 percent of all organisms estimated to have been entrained during the two-year study. Eggs accounted for nearly all remaining estimated entrainment. A majority of estimated annual entrainment occurred during periods extending from mid-May to mid-June during 2015 and from mid-May to early June during 2016. No significant differences in entrainment density were observed among the diel sampling intervals for any development stage during either study year when combining all taxa together or within major taxonomic groups.

Invasive, non-native Asian carps, including silver carp, bighead carp, and grass carp, dominated the entrainment samples at the LEC during 2015 and 2016[1]. These species have been expanding their range throughout the Mississippi River basin during recent decades and are now abundant in numerous river systems, including the LMOR. Asian carps are generally regarded as nuisance species that have the potential to cause ecological harm to native fishes and other aquatic organisms due to their ability to alter water quality and obtain high densities. Their dominance in entrainment samples collected at the LEC likely can be attributed to life history traits as they are known to have high fecundity rates with females producing hundreds of thousands of pelagic eggs that develop into larvae while drifting in turbulent waters. However, because they are considered to be invasive and undesireable, and because MDNR recently clarified in related NPDES permitting discussions their interest in de-emphasizing Asian carps, they were not considered further in the 316(b) BPJ considerations.

Other than Asian carps, the remaining 1.5 billion fishes estimated to have been entrained during the two study years consisted primarily of minnows in the family Cyprinidae (410 million) as well as common carp ([*Cyprinus carpio*] 18 million); freshwater drum (146 million); shads (*Dorosoma* spp.) primarily represented by gizzard shad (135 million); carpsuckers and buffalos in the subfamily Ictiobinae (118 million); mooneyes in the family Hiodontidae (44 million); and unidentified fishes (598 million). Based on past and recent monitoring efforts, gizzard shad and freshwater drum are among the most abundant taxa present in the LMOR near the LEC, which increases the probability of entrainment of their larvae. The pelagic eggs of freshwater drum, a broadcast spawner like Asian carp, is also susceptible to entrainment. Entrainment of remaining taxa likely was associated with their distribution and abundance near the LEC as a high diversity of minnows occur in the LMOR and river carpsucker, smallmouth buffalo, and goldeye have been collected in high numbers during past monitoring efforts.

Recreationally valuable game fish, including species of catfish (family Ictaluridae), white bass (*Morone chrysops*), sauger (*Sander canadensis*) and walleye (*Sander vitreus*), as well as panfish, such as sunfishes (*Lepomis* spp.) and crappies (*Pomoxis* spp.), collectively represented less than one percent of the total entrainment estimate after excluding Asian carps. Many of these taxa have life history traits that likely reduce their susceptibility to entrainment, such as producing demersal, adhesive eggs as opposed to buoyant eggs that drift in the water column. Furthermore, catfishes and sunfishes deposit eggs in nests and guard young for a period of time following hatching.

More detailed information on the methodology and results of the 2015 – 2016 study performed at the LEC may be found in the *§ 122.21(r)(9) Entrainment Characterization Study* submittal report.

1.4.3.2 Comprehensive Technical Feasibility and Cost Evaluation Study – 40 CFR 122.21(R)(10)

As part of the § 122.21(r)(10) requirement, the technical feasibility of the following alternatives for entrainment reduction were evaluated at the LEC:

- Retrofit to a closed-cycle recirculating system (CCRS)
- Fine-mesh screens with a mesh size of 2 mm or smaller
- Reuse of water or alternative sources of cooling water

[1] Asian carps collectively accounted for between 84 and 85 percent of the entrainment samples at the LEC in 2015 and 2016, respectively.

- An evaluation of any other technologies for reducing entrainment as identified by the applicant or requested by the Director of the USEPA

Entrainment losses could be reduced most significantly by conversion to closed-cycle cooling. However, this option requires disproportionately high capital and operating costs, and would slightly reduce plant generation capacity. While all cooling tower types pose challenges during both construction and operations periods or are simply infeasible, the evaluation found that mechanical draft cooling towers would pose the fewest challenges at the LEC. The capital cost to retrofit all four LEC units to closed-cycle cooling was estimated to be approximately $432 million with annual Operations & Maintenance (O&M) costs of approximately $15 million. The present value[2] of social costs (compliance and power system costs) to retrofit to a CCRS were estimated over a 30-year period to be approximately $592 million using a three percent discount rate and $307 million using a seven percent discount rate.

Installation of fine-mesh modified TWS at the LEC would require an expansion of screen surface area to maintain the existing cooling water flow rate, plant generation capacity, and existing through-screen velocity. Thus, two alternatives for installing fine-mesh that expand gross screen area were evaluated for the LEC: the use of modified dual-flow TWS with 2 mm fine-mesh panels installed in the existing CWIS and expanding the existing CWIS to use modified thru-flow TWS with 0.5 mm fine-mesh panels. The installation of narrow-slot submerged cylindrical wedgewire screens was found to be impractical at the LEC due to the proximity to the navigational channel and debris loading.

Replacing the existing thru-flow coarse-mesh TWS with dual-flow TWS with 2 mm screen mesh would help maintain the current through-screen velocity but introduce a host of uncertainties that would necessitate further study to confirm feasibility. The estimated project capital cost to install modified dual-flow TWS with 2 mm fine-mesh screen panels and a fish return system was approximately $20 million with annual O&M costs of approximately $280,000. The present value of social costs under this option was estimated to be approximately $16 million using a three percent discount rate and $9 million using a seven percent discount rate.

Use of 0.5-mm mesh would exclude more organisms – valuable, less valuable, and invasive species – and would necessitate an intake expansion to maintain the current through-screen velocity. The estimated project capital cost to expand the CWIS and install modified TWS with 0.5 mm fine-mesh and a fish return system was approximately $49 million with annual O&M costs of approximately $0.5 million. The present value of social costs under this option was estimated to be approximately $40 million using a three percent discount rate and $22 million using a seven percent discount rate.

Water reuse was considered infeasible at the LEC due to the limited sources available which would be insufficient to meet the cooling water requirements at the LEC. The use of an alternative water supply, mainly groundwater, was considered technically infeasible due to the large amount of water required that could affect the regional aquifer. Other technologies listed in the Rule (e.g., barriers) were deemed not technically infeasible at the LEC due to large scale required or the inability of the technology to function correctly in the Missouri River.

1.4.3.3 Benefits Valuation Study – 40 CFR 122.21(R)(11)

The LEC conducted a Benefits Valuation Study to meet the final § 316(b) Rule requirements under § 122.21(r)(11). These requirements are to estimate the biological and economic benefits that

[2] A hypothetical 30-year lifecycle was used to evaluate the costs and benefits of each CWIS technological option. Use of this conservatively long lifecycle causes annualized cost values to be underestimated and any corresponding benefits to be overestimated.

are likely to accrue with implementation of the technology and operational alternatives evaluated in the § 122.21(r)(10) study. Site-specific entrainment information from the *§ 122.21(r)(9) Entrainment Characterization Study* and impingement information from a past study were used to establish baseline losses of representative target species and to determine the reductions in mortality expected with each alternative technology evaluated. These reductions in mortality were then quantified in biological units and monetized using appropriate economic valuation methods consistent with those used in the final 316(b) rulemaking process.

The alternative technologies, which were evaulated against existing operations as baseline, included installation of 2-mm modified (fish-friendly) fine-mesh TWS in the existing intake structure coupled with a fish return system; installation of an expanded intake structure with 0.5-mm fish-friendly fine-mesh TWS coupled with a fish return system; and retrofit to a CCRS through the installation of mechanical draft cooling towers. No alternate water sources or water reuse options were found to be feasible at the LEC, therefore the benefits of alternate water sources were not evaluated.

Target species assessed in the study were minnows in the family Cyprinidae, gizzard shad, freshwater drum, and channel catfish. The four target species contribute to all economic benefits categories (i.e., recreational/commercial fishing and forage species) and collectively accounted for 35.2 – 43.9 percent of total annual non-Asian carp entrainment and 94.5 percent of non-Asian carp impingement at the LEC (ASA and Alden 2008). Despite accounting for more than 80 percent of entrainment at the LEC, invasive Asian carp were not included as a target species as the protection of their eggs and larvae would have little or no benefits to fishermen and likely would exacerbate the negative effects of these species in the LMOR[3]. Propagating this invasive species is not a fisheries goal within the LMOR.

Annual baseline losses due to entrainment (two study years: 2015 and 2016) and impingement (one study year: 2005 – 2006) were estimated based on sampling densities observed during each respective study year paired with cooling water flows from the 2015 – 2016 entrainment characterization study. Losses were adjusted for each alternative technology evaluated based on expected rates of exclusion and survival of each species and life stage as well as reductions in cooling water flows.

Total annual baseline losses of target species due to entrainment were approximately 346 million organisms during the 2015 study year and 319 million organisms during the 2016 study year. Reduced estimates of total losses ranged from 0 to 342 million organisms across the technology alternatives and study years.

Total annual baseline losses of target species due to impingement were approximately 2.7 million and 2.5 million fish when pairing impingement densities from the 2005 study year with flows from the 2015 and 2016 study years, respectively. Reduced estimates of total losses ranged from 0 to 1.3 million fish across the technology alternatives and study years.

Biological benefits are defined as the predicted increases in annual fishery yield (in weight) resulting from reduced losses associated with each technology alternative. Separate measures are calculated for species of commercial/recreational fishing importance and forage species using methods based in well-establish fishery management techniques. The total biological benefits of

[3] Asian carp are invasive, nonnative species that provide neither direct nor indirect benefits to LMOR recreational and commercial fisheries and have the potential to cause negative impacts to overall ecosystem health. These reasons are discussed further in the *§ 122.21(r)(11) Benefits Valuation Study* submittal report and are the basis of the State of Nebraska's designation of Asian carp as a nuisance species not subject to BTA protection under 40 CFR 125.92(b) (Letter from S.M. Goans, Nebraska Department of Environment and Energy, to M. Krumland, Nebraska Public Power District dated August 2, 2019).

reduced entrainment for the technology alternatives considered at the LEC, estimated as the increased fishery yield, ranged from 1,772 to 21,721 pounds (lbs) depending on study year and alternative. The total biological benefits of reduced impingement for the technology alternatives ranged from 13,719 to 27,798 lbs depending on study year and alternative.

The economic benefit for each alternative was calculated by assuming that the economic value of fish entrained or impinged is equivalent to the total economic benefit that could accrue to the public, had they not been entrained or impinged under that alternative. Benefits were calculated for four categories: market direct use benefits, non-market direct use benefits, indirect use benefits, and non-use benefits, using standard natural resource valuation methods. The benefits of each technology alternative were assumed to accumulate over a period of 30 years to estimate net present value (NPV) using discount rates of three and seven percent.

Across all alternatives, estimates of the annual economic benefits from reductions in entrainment loss ranged from approximately $700 to slightly more than $10,000 per year, depending on study year and alternative. Estimates of annual economic benefits from reductions in impingement loss ranged from just over $2,000 to almost $5,000 per year across the alternatives and study years. Finally, total annual benefits from reductions in entrainment and impingement combined ranged from just over $3,000 to just over $15,000 per year across the alternatives and study years.

NPV of lifetime benefits of entrainment and impingement reductions over the 30-year period used for the analysis ranged from just over $18,000 to almost $208,000, depending on study year, alternative and assumed discount rate (three vs seven percent). Most of this benefit was a result of reductions in entrainment loss of the forage base.

More detailed information on the methodology and results may be found in the *§ 122.21(r)(11) Benefits Valuation Study* submittal report.

1.4.3.4 Non-Water Quality Environmental and Other Impacts Study – 40 CFR 122.21(R)(12)

The 122.21(r)(12) requirement calls for assessment of the following impacts (which can be positive or negative depending on the facility and technology at issue), at a minimum, for each of the technologies evaluated in § 122.21(r)(10):

- Estimates of changes to energy consumption associated with parasitic load, loss of generation efficiency, and downtime associated with construction
- Estimates of increases in air emissions
- Estimates of changes in noise generation
- Discussion of potential impacts to safety
- Discussion of potential impacts to facility reliability
- Estimation of changes in water consumption
- Discussion of efforts to mitigate these adverse effects

While the *§ 122.21(r)(12) Non-Water Quality Environmental and Other Impacts Study* submittal report addresses these issues for each of the candidate technologies, potential retrofit with either fine-mesh modified TWS option (dual-flow screens with 2 mm mesh in the existing intake or 0.5 mm in an expanded intake) exhibit relatively modest effects compared to closed-cycle cooling.

The net energy loss associated with the CCRS would be approximately 39 MW during average summer conditions and 23 MW during average winter conditions. Energy losses would not be anticipated to compromise local grid reliability as other facilities could make up for the reduction in generating capacity. Following the conversion of all four generating units to closed-cycle cooling, increases in emissions associated with replacement energy generation would amount to approximately 221,600 tons of CO_2, 490 tons of SO_2, 124 tons of NO_x, and 9,290 tons of particulate matter (PM) annually. Furthermore, retrofit to a CCRS would cause increased noise levels near the cooling towers and consumptive water use to increase.

The use of 2 mm dual-flow fine-mesh screens would result in no appreciable changes to energy consumption in comparison to the anticipated future baseline operating condition of impingement compliant modified TWSs. Meanwhile, the use of 0.5 mm fine-mesh screens in an expanded CWIS would require an estimated maximum additional auxiliary load of approximately 0.9 MW. The changes in emissions, noise, plant reliability, and consumptive water use due to either fine-mesh screen-system would be negligible.

1.4.3.5 Peer Review – 40 CFR 122.21(R)(13)

The reports prepared under 40 CFR 122.21(r)(10) through (12) were peer-reviewed by external experts as required by 40 CFR 122.21(r)(13). The three peer reviewers are qualified experts in power plant engineering, aquatic biology, and resource economics, respectively. The qualifications of the peer reviewers were submitted to MDNR for review and approval and following their completion of a conflict of interest questionnaire, were subsequently approved by MDNR. Consistent with the final § 316(b) Rule's requirements, the § 122.21(r)(13) submittal report provides the peer reviewers' qualifications, the full set of peer reviewer's comments, and Ameren's responses. The peer reviewers each concurred that the 40 CFR 122.21(r)(10) through (12) reports all met the requirements of the Rule and were technically sound. The peer reviewers each concurred that Ameren's responses addressed their comments and suggestions, as documented in the § 122.21(r)(13) submittal report.

1.4.4 Assessment of Entrainment BTA

In this section, each of the eleven factors the final § 316(b) Rule identifies as relevant when assessing entrainment BTA on a site-specific BPJ basis, are considered. Section 1.4.4.1 discusses the five factors the Director *must* consider. Section 1.4.4.2 discusses the six factors the Director *may* consider. Both sets of factors are listed in this excerpt from the Rule (40 CFR 125.98(f)):

§ 125.98 Director requirements.

(f) Site-specific entrainment requirements.

(2) The proposed determination in the fact sheet or statement of basis <u>must</u> be based on consideration of any additional information required by the Director at § 125.98(i) and the following factors listed below. The weight given to each factor is within the Director's discretion based upon the circumstances of each facility.

(i) Numbers and types of organisms entrained, including, specifically, the numbers and species (or lowest taxonomic classification possible) of Federally-listed, threatened and endangered species, and designated critical habitat (e.g., prey base);

(ii) Impact of changes in particulate emissions or other pollutants associated with entrainment technologies;

(iii) Land availability inasmuch as it relates to the feasibility of entrainment technology;

(iv) Remaining useful plant life; and

(v) Quantified and qualitative social benefits and costs of available entrainment technologies when such information on both benefits and costs is of sufficient rigor to make a decision.

(3) The proposed determination in the fact sheet or statement of basis <u>may</u> be based on consideration of the following factors to the extent the applicant submitted information under 40 CFR 122.21(r) on these factors:

(i) Entrainment impacts on the waterbody;

(ii) Thermal discharge impacts;

(iii) Credit for reductions in flow associated with the retirement of units occurring within the ten years preceding October 14, 2014;

(iv) Impacts on the reliability of energy delivery within the immediate area;

(v) Impacts on water consumption; and

(vi) Availability of process water, gray water, waste-water, reclaimed water, or other waters of appropriate quantity and quality for reuse as cooling water.

For each factor, the following provides references to the relevant section(s) of the submittal reports and a summary of findings relative to that factor.

1.4.4.1 Entrainment BTA Factors that Must Be Considered

This section addresses the factors that MDNR <u>must</u> consider under 40 CFR 125.98(f)(2).

<u>Numbers and Types of Entrained Organisms</u>

<u>Key Document Section(s):</u> The *§ 122.21(r)(9) Entrainment Characterization Study* submittal report for methods and comprehensive results; The *§ 122.21 (r)(11) Benefits Valuation Study* submittal report – Section 3 for baseline rates of entrainment of Target Species.

The methods employed during the 2015 – 2016 entrainment characterization study conducted at the LEC and detailed results are presented in the *§ 122.21(r)(9) Entrainment Characterization Study* submittal report. This effort resulted in collected data consistent with the requirements of the Rule, including characterization of seasonal and diel variation in entrainment rates and estimates of total annual entrainment based on actual intake flows observed during the two-year study. The *§ 122.21 (r)(11) Benefits Valuation Study* uses baseline rates of entrainment from the § 122.21(r)(9) report for a subset of Target Species to estimate the benefits of using several potentially feasible entrainment reduction technologies at the LEC.

No federal or state-listed T&E species were among the 19 species and 12 families identified during the study. Invasive, non-native Asian carp, including silver carp, bighead carp, and grass carp, comprised the vast majority (approximately 84 to 85%) of estimated entrainment at the LEC. Asian carp species are known to be highly abundant in the LMOR. These fishes are generally regarded as nuisance species that have the potential to cause ecological harm to native fishes and other aquatic organisms. Asian carps are highly fecund broadcast spawners with pelagic eggs, which may make them particularly susceptible to entrainment at the LEC CWIS. Further discussion of the negative effects of Asian carps to ecosystem health and their exclusion from the benefits valuation analysis is provided in Section 3.4 of the *§ 122.21 (r)(11) Benefits Valuation Study* submittal report. Removing Asian carps from the entrainment estimates, estimated entrainment was approximately 981 million organisms in 2015 and 505 million organisms in 2016[4]. The observed difference in estimated entrainment between the two years was most likely a result of natural biological processes and not related to differences in cooling water intake operation.

[4] Total entrainment was estimated to be 6.2 billion in 2015 and 3.6 billion in 2016.

Larvae comprised approximately 99 percent of all organisms estimated to have been entrained during the two-year study with eggs accounting for nearly all remaining estimated entrainment.

Other than Asian carps, most of the fishes entrained at the LEC consisted of minnows in the family Cyprinidae, common carp, freshwater drum, shads primarily represented by gizzard shad, carpsuckers and buffalos, mooneyes including goldeye, and unidentified fishes. Recent population surveys reviewed for § 122.21(r)(4) submittal report indicate that these taxa are among the most abundant fishes in the LMOR near the LEC, which increases the probability of entrainment of their larvae. Recreationally valuable gamefish collectively comprised less than one percent of the total entrainment estimate without Asian carps. Additionally, the LEC withdraws a smaller fraction of LMOR during the peak entrainment periods. As such, Ameren does not believe the number and types of organisms entrained provide a compelling basis under the final § 316(b) Rule to adopt additional entrainment measures.

Impacts of Changes in Emissions of Particulates and Other Pollutants

Key Document Section(s): The *§ 122.21(r)(12) Non-Water Quality Environmental and Other Impacts Study* submittal report – Section 4.2 for discussion of estimated air pollutant emissions and associated impacts resulting from cooling towers, modified dual-flow TWS with 2 mm fine-mesh panels, and modified TWS with 0.5 mm fine-mesh panels within an expanded CWIS.

The entrainment BTA assessment considers changes in pollutant emissions in the *§ 122.21(r)(12) Non-Water Quality Environmental and Other Impacts Study* submittal report. There are two types of emissions associated with the operation of a cooling tower: (1) PM emissions directly from the cooling tower, and (2) Stack emissions associated with the replacement energy generation (to operate cooling tower fans and pumps, and overcome backpressure energy penalty of the turbine). Under the first factor, the operation of cooling towers at the LEC is estimated to increase total PM emissions by a maximum of 20 tons per year (tpy). Under the second factor, the increased emissions associated with replacement energy generation following the complete conversion to closed-cycle cooling is estimated to be approximately 221,600 tons of CO_2, 490 tons of SO_2, 124 tons of NO_x, and 9,290 tons of PM annually (Table 1-3).

The operation of mechanized equipment to modify the CWIS for either fine-mesh screen option (2 mm mesh in the existing intake or 0.5 mm mesh in an expanded intake) would produce localized emissions which would be short-term and minor. Replacement energy generation would not be appreciable for the 2 mm fine-mesh dual-flow TWS modification, but it would be anticipated for the expanded CWIS with 0.5 mm fine-mesh screen modification. The estimated increased emissions following conversion to this technology alternative is approximately 20 tons of CO_2, <0.1 tons of SO_2, <0.1 tons of NO_x, and 0.8 tons of PM annually (Table 1-3).

Table 1-3 Incremental indirect air emissions due to reduced generating capacity at the LEC following full conversion to each candidate technology.

Average Increase in Emissions (tons/yr):	Technology		
	Mechanical Draft Cooling Towers	Modified Dual-Flow TWS with 2-mm Fine-Mesh	Expanded CWIS with Modified TWS with 0.5-mm Fine-Mesh
Carbon dioxide (CO_2)	221,600	Negligible	19.67
Sulfur dioxide (SO_2)	490		0.04
Nitrogen oxides (NO_x)	124		0.01
Total particulate matter (PM)	9,290		0.82

While each alternative cooling water technology would increase emissions, the potential increase in health or other impacts that could result from increases in emissions associated with any of these technology retrofits would be small. As such, the change in emissions was not identified as a key factor in the determination of entrainment BTA.

Land Availability

Key Document Section(s): The *§ 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study* submittal report – Section 3.2.5 for the theoretical arrangement of cooling towers at the LEC; Section 6.1 for modified dual-flow TWS with 2 mm fine-mesh panels; Section 6.2 and Appendix A for modified TWS with 0.5 mm fine-mesh panels within an expanded CWIS.

The theoretical arrangement of mechanical draft cooling towers evaluated at the LEC would place the four towers north of the plant on land owned by Ameren that is currently used for agriculture. This location was chosen instead of alternatives located in closer proximity to the plant so that the exhaust plume would not pose safety concerns within the main plant by way of fog or ice.

Installation of modified dual-flow TWS with 2 mm fine-mesh panels and a fish return system would not be impacted by unavailability of land. The new fine-mesh modified dual-flow TWS would be installed in the existing CWIS following modifications to accommodate them, replacing the existing TWSs and requiring no additional land.

Installation of 0.5 mm fine-mesh modified TWS would, however, require the LEC CWIS to be expanded considerably to increase the gross screen surface area and maintain the existing cooling water flow rate and through-screen velocity. The theoretical design evaluated at the LEC would extend the CWIS by 125 feet upstream and 125 feet downstream from the current structure boundaries and would also extend approximately 17 feet farther into the river. A fish handling and return system would be installed for all bays with the system for the upstream side of the CWIS having to be piped past the downstream intakes for safe return into the river. As such, this technology would result in the conversion of both undeveloped lands, riparian zones, and in-stream habitats to developed uses.

Remaining Useful Plant Life

Key Document Section(s): The *§ 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study* submittal report – Section 3.2.7; Section 6.1.2; Section 6.2.2; Appendix C, Section 4.2; and Appendix E, Section 1.1.

There are no plans for shutting down the LEC or to significantly alter its operations. However, a hypothetical 30-year lifecycle was used to evaluate the costs and benefits of each CWIS technological option. Use of this conservatively long lifecycle causes annualized cost values to be underestimated and any corresponding benefits to be overestimated.

Quantitative and Qualitative Social Benefits and Social Costs

Key Document Section(s): The *§ 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study* submittal report – Section 3.2.8 for cooling tower costs; Section 6.1.3 for costs to install modified dual-flow TWS with 2 mm fine-mesh panels; Section 6.2.3 for costs to expand the existing CWIS and install modified TWS with 0.5 mm fine-mesh panels; The *§ 122.21 (r)(11) Benefits Valuation Study* submittal report – Section 5.2 and Table 5-4 for benefits of each candidate technology.

Ameren has estimated the social costs and social benefits associated with alternative entrainment control measures in a manner consistent with the Rule's requirements and subject to expert peer review.

- The estimation of total social benefits included both use benefits as well as potential nonuse benefits. Necessary assumptions were intentionally designed to bias social benefits high and no reasonably foreseeable benefits were left un-monetized.
- Social cost estimates omit those cost categories for which the magnitude of the social costs was uncertain. Assumptions related to those social cost components that were monetized were intended to bias social costs low.

Ameren believes considering the net social benefits of a potential activity is a sound means of deciding whether the activity represents entrainment BTA on a BPJ basis. The Rule allows MDNR the discretion to "reject otherwise available entrainment controls if the costs of the controls are not justified by their associated benefits (taking into account monetized, quantified, and qualitative benefits), and the other factors discussed in the final Rule." In the event the net social benefits of a proposed set of activities are negative (i.e., social costs outweigh social benefits such that expenditures to install and operate the measure do not result in a commensurate social benefit), there is no reasonable justification for that activity to represent entrainment BTA as doing so is expected to leave society worse off.

The social costs and social benefits documented in the § 122.21(r)(9) through (12) submittal reports for closed-cycle cooling, modified dual-flow TWS with 2 mm fine-mesh panels, and expanding the existing CWIS and installing modified TWS with 0.5 mm fine-mesh panels are presented below in Figure 1-4[5].

Implementing any of the candidate entrainment measures would result in strongly negative net social benefits. Retrofit to closed-cycle cooling has the most negative net social benefits, estimated at approximately *-$592 million*[6]. Both options considered for installing fine-mesh-modified TWS at the LEC also have strongly negative net social benefits that ranged from approximately *-$40 million* to expand the CWIS and install modified TWS with 0.5 mm fine-mesh panels to approximately *-$16 million* to install modified dual-flow TWS with 2 mm fine-mesh panels.

[5] Results are expressed as present value at a three percent discount rate. The essential conclusions are unchanged using a seven percent discount rate.
[6] For clarity, negative numbers are depicted in red, italic font.

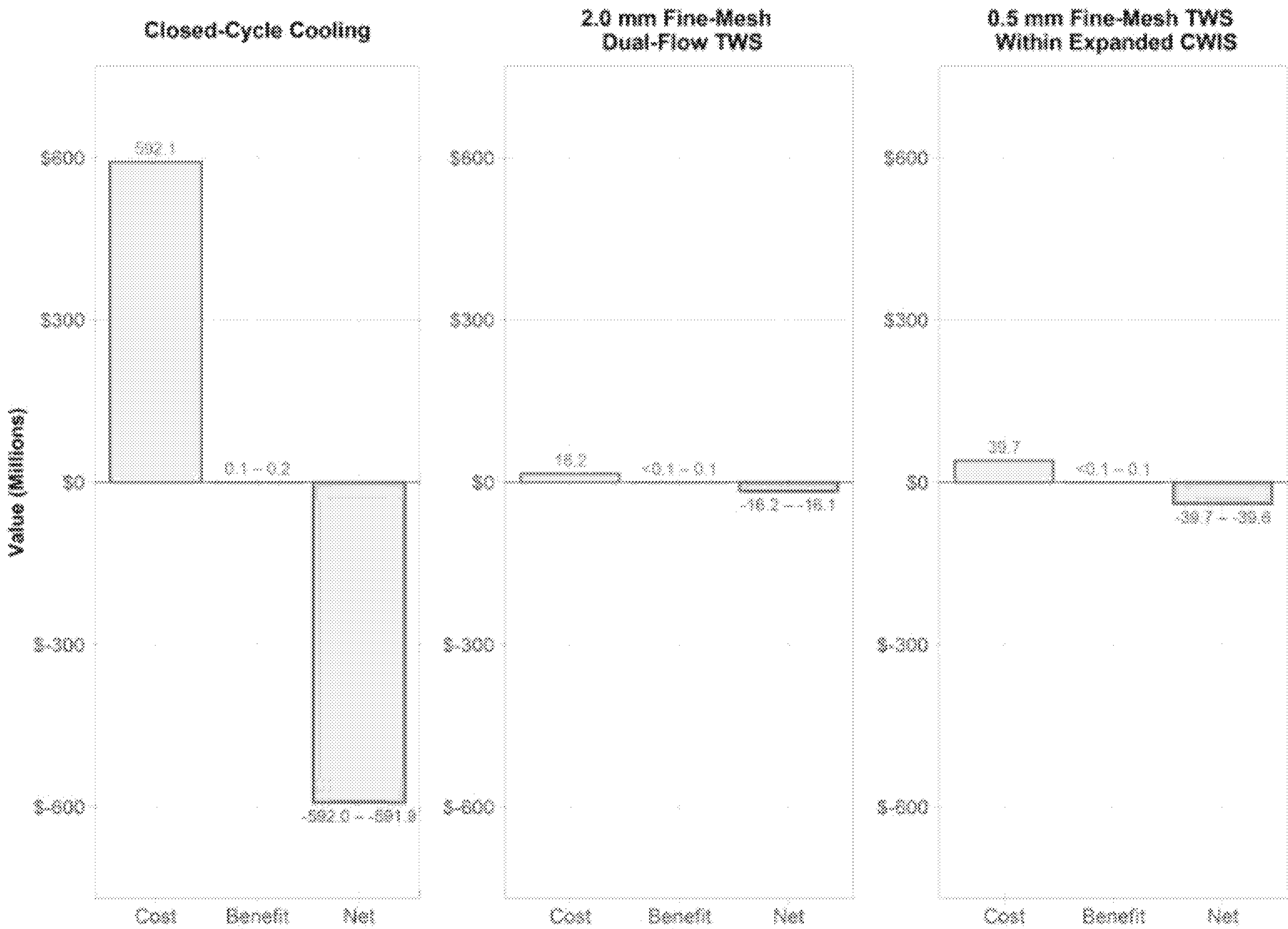

Figure 1-4 Comparison of social benefits and costs for retrofit to closed-cycle cooling, modified dual-flow TWS with 2 mm fine-mesh panels, and modified TWS with 0.5 mm fine-mesh panels with an expansion of the existing CWIS at the LEC – present value calculated at a three percent discount rate.

1.4.4.2 Entrainment BTA Factors That May Be Considered

The following are the findings of the entrainment BTA assessment relative to the factors that MDNR may consider under 40 CFR 125.98(f)(3).

Entrainment Impacts on the Waterbody

Key Document Section(s): The *§ 122.21(r)(9) Entrainment Characterization Study* submittal report for methods and comprehensive results; The *§ 122.21 (r)(11) Benefits Valuation Study* submittal report – Sections 3 and 4 for baseline rates of entrainment and equivalent loss estimates of Target Species; The *§ 122.21(r)(4) Source Water Baseline Biological Characterization Data* submittal report – Section 5 for the status of the fish community in the LMOR.

As reported in the *§ 122.21(r)(9) Entrainment Characterization Study* submittal report, excluding Asian carps, the number of fish eggs, larvae and juveniles estimated to have been entrained at the LEC was 981 million in 2015 and 505 million in 2016. In contrast, the number of Asian carps entrained during 2015 and 2016 was estimated to be 5.2 billion and 3.1 billion, respectively. Larvae of invasive, non-native Asian carps, particularly silver carp and bighead carp, dominated collections, accounting for 85 percent of estimated entrainment during the two-year study. Asian carps are considered to be nuisance species that provide little or no benefit to recreational and commercial fisheries and have the potential to cause negative impacts to overall ecosystem health in the LMOR. As such, the removal of these individuals may be considered to have positive effects on the waterbody as a whole.

Remaining identifiable entrainment primarily was comprised of common carp, other minnows, freshwater drum, shads (primarily gizzard shad), carpsuckers and buffalos, and mooneyes. In contrast, recreationally valuable game fish and panfish collectively represented less than one percent of the total entrainment estimate after excluding Asian carps. Minnows, gizzard shad, freshwater drum, and channel catfish were chosen as Target Species for the *§ 122.21 (r)(11) Benefits Valuation Study* submittal report, which estimated baseline losses due to entrainment in equivalent fishery yields of approximately 11,000 lbs and 17,000 lbs during 2015 and 2016, respectively. No federal or state-listed T&E species were identified during the entrainment characterization study.

Entrainment sampling previously was conducted at the LEC during 1974 and 1975 (EEH 1976a), when in-river biological monitoring was also conducted in the immediate vicinity of the plant (EEH 1976b). Minnows other than common carp, herrings, and mooneyes accounted for nearly 90 percent of the larvae collected during the entrainment study. Although these taxa comprised a majority of the identifiable larvae collected during the recent 2015 – 2016 study after excluding Asian carp, the relative abundance of freshwater drum, carpsuckers, buffalos, common carp, and other fishes noticeably increased in comparison to the historical sampling. These taxa were also among the most numerous collected from the LMOR during population surveys reviewed in the *§ 122.21(r)(4) Source Water Baseline Biological Characterization Data* submittal report.

In conclusion, Asian carp, which have the potential to cause ecological harm to biological communities in the LMOR, were the most entrained at the LEC, whereas historically abundant taxa continue to be among the most numerous fishes collected in the river. Furthermore, the relevant abundance of other species has increased over the period that the plant has operated as trends of increasing richness and diversity have been observed. Additionally, the LEC withdraws a smaller fraction of the LMOR during the peak entrainment period. State and federal-listed T&E species have not been identified in entrainment samples. Given these findings, it is likely that entrainment at the LEC has little to no impact on the LMOR.

Thermal Discharge Impacts

Key Document Section(s): The *§ 122.21 (r)(11) Benefits Valuation Study* submittal report – Section 5.3.

Thermal discharges are independently regulated as a pollutant under the Clean Water Act which requires each facility to either meet existing water quality criteria for temperature or obtain a site-specific variance under § 316(a) of the Clean Water Act. By meeting existing water quality criteria for temperature a facility is protective of aquatic resources while a § 316(a) variance can only be granted if the site-specific thermal limits ensure the protection of balanced indigenous communities in the receiving water body. The LEC intends to submit to MDNR a demonstration under Section 316(a) seeking the establishment of a site-specific thermal limitation and a variance from existing thermal standards. As any variance granted must ensure the continue protection of a balaced indigenous community, any reductions in thermal discharge, such as through installation of cooling towers will not have any demonstrable benefits to the aquatic community in the vicinity of the LEC as the variance ensures that the community is already protected from the discharge of heat.

Flow Reduction with Earlier Unit Retirement

Key Document Section(s): The *§ 122.21 (r)(5) Cooling Water System Data* submittal report – Sections 2 and 3.

The LEC currently consists of four coal-fired units (Units 1-4), which originally came online between 1970 and 1973. The LEC has not retired any generating units and at this time there are no plans to retire any units.

Impacts on Reliability of Energy Delivery

Key Document Section(s): The *§ 122.21(r)(12) Non-Water Quality Environmental and Other Impacts Study* submittal report – Section 4.5 for cooling towers, modified dual-flow TWS with 2 mm fine-mesh panels, and modified TWS with 0.5 mm fine-mesh panels within an expanded CWIS.

The § 122.21(r)(12) submittal report reviews each candidate technology considered in the entrainment BTA assessment for the LEC for its potential impacts to the plant's ability to reliably produce power when its regional transmission organization requires it to.

Electric system reliability is a measure of the ability of the system to deliver power to consumers within accepted standards and in the amount desired. Reliability encompasses two concepts: adequacy and security. Adequacy implies that there are sufficient generation and transmission resources installed and available to meet projected electrical demand, taking into account scheduled and unscheduled outages of system facilities. Security implies that the system will remain intact operationally (i.e., will have sufficient available operating capacity) even after outages or other equipment failure.

At the facility level, the lost energy due to outages during the cooling tower retrofit, the additional auxiliary load, and turbine efficiency loss at the LEC would not be anticipated to compromise the local grid reliability because other facilities belonging to the Midcontinent Independent System Operator (MISO) regional transmission organization would likely be able to make up for the reduction in generating capacity. As such, impacts on reliability of energy delivery can be reasonably disregarded in the determination of BTA. However, grid reliability could be impacted in the event multiple MISO facilities have reduced generation due to cooling tower energy penalties, outages, or regulation-induced premature retirements. Coordination with MISO and other regional facilities would be necessary to ensure grid reliability impacts are minimized.

The installation of fine-mesh modified traveling screens under either option (dual-flow TWS with 2 mm fine-mesh panels or 0.5 mm fine-mesh screens within an expanded CWIS) could allow for staged implementation of new screens for each individual generating unit, and it is expected that the unit outage necessary for conversion would be short, and potentially avoidable altogether. Once installed, the operation of the modified CWIS would not result in appreciable changes to facility reliability. Therefore, no significant impacts to facility reliability are anticipated in association with the use of fine-mesh modified traveling screens.

Impacts on Water Consumption

Key Document Section(s): The *§ 122.21(r)(12) Non-Water Quality Environmental and Other Impacts Study* submittal report – Section 4.6 for cooling towers, modified dual-flow TWS with 2 mm fine-mesh panels, and modified TWS with 0.5 mm fine-mesh panels within an expanded CWIS.

The § 122.21(r)(12) submittal report evaluates changes in water consumption associated with each candidate technology considered in the entrainment BTA assessment for the LEC.

Cooling towers consume water through evaporation, as a portion of the circulating water in the cooling tower evaporates in order to cool the remainder of the water. Consumptive water use from operating mechanical draft cooling towers at the LEC is estimated to be between 8 and 12 gpm/MW, or up to 720 gal/megawatt-hour. At 100 percent capacity factor, this equates to a maximum of approximately 31,000 gpm of water consumption. Groundwater collector wells (Ranney wells) would supply all make-up water for the CCRS. Groundwater in the vicinity is recharged by surface water, which most notably comes from the LMOR. In recent years, the mean flow of the LMOR near the LEC has been 99,210 cfs (or 44,000,000 gpm) (USGS 2019). Compared to the availability of groundwater and surface water resources in the vicinity, the amount of consumptively used, even at the maximum rate of approximately 31,000 gpm or 0.07 percent of LMOR flow, would be negligible. Therefore, no significant impacts from water consumption are anticipated and can be reasonably disregarded in the determination of BTA.

The installation of fine-mesh modified traveling screens under either option (dual-flow TWS with 2 mm fine-mesh panels or 0.5 mm fine-mesh screens within an expanded CWIS) would maintain the current intake flow and cooling water would be returned to the LMOR. Therefore, the use of this technology would not result in appreciable changes in water consumption and can be reasonably disregarded in the determination of BTA.

Availability of Alternative Water Supplies

Key Document Section(s): The *§ 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study* submittal report – Sections 8 and 9.

The § 122.21(r)(10) submittal report reviewed potential alternate water sources in the vicinity of the LEC, including the reuse of wastewater and the withdrawal of groundwater. However, no alternative sources were found to be feasible.

1.4.5 Summary of Entrainment BTA and Recommendations

The final § 316(b) Rule's summary of the requirements of the NPDES Director includes the following section under 40 CFR 125.98(f), Site-specific entrainment requirements:

(4) If all technologies considered have social costs not justified by the social benefits, or have unacceptable adverse impacts that cannot be mitigated, the Director may determine that no additional control requirements are necessary beyond what the facility is already doing. The Director may reject an otherwise available technology as a BTA standard for entrainment if the social costs are not justified by the social benefits.

Based on the review of the findings presented in the § 122.21(r)(10) through (12) submittal reports, Ameren believes the net social benefits (i.e., social benefits minus social costs) presented in Section 0 are the best and most complete factor for assessing potential retrofits to mitigate entrainment. This conclusion is based on a number of considerations:

- The comparison of social costs and social benefits integrates several decision factors available to MDNR. For example, the social costs of potential retrofits directly reflect:
  - Land availability;
  - Remaining useful plant life; and
  - Mitigation of potential impacts to facility reliability.
- Similarly, estimates of beneficial biological changes directly incorporate:
  - Numbers and types of organisms entrained;
  - Remaining useful plant life; and
  - Entrainment impacts on the waterbody.

Monetizing social costs and social benefits facilitates comparison of disparate changes using a common metric. Consistent with this policy objective, Ameren has carefully estimated total social benefits (e.g., all beneficial changes are identified) and willingness-to-pay for those changes has been conservatively (tending to overstate willingness-to-pay) estimated. At the same time, social costs have intentionally been underestimated through a series of conservative assumptions or by simply omitting social cost components if their magnitude was generally uncertain (e.g., monetization of air emissions, noise, and potential safety effects). Thus, when a technology is identified as generating social costs that are greater than social benefits, there is a very high degree of certainty that identification of that technology as BTA would, in fact, leave society worse off.

Ameren has assessed the social costs and social benefits of potentially retrofitting to closed-cycle cooling or potential installation of fine-mesh screens, including either modified dual-flow TWS with 2 mm fine-mesh or modified TWS with 0.5 mm fine-mesh within an expanded CWIS. These approaches are highly impractical and would result in strongly negative net social benefits (that is, the social costs are not justified by the social benefits). The following are brief summaries of the potential entrainment BTA measures.

1.4.5.1 Retrofit to Closed-Cycle Cooling

Key Document Section(s): The *§ 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study* submittal report – Sections 8 and 9.

The closed-cycle cooling study selected mechanical draft cooling towers as the least challenging cooling tower arrangement at LEC when compared to the other cooling tower alternatives. The capital cost to retrofit all four LEC units was estimated to be approximately $432 million with an annual O&M costs estimated to be $15 million. The present value[7] of social costs associated with non-water quality environmental and other impacts to retrofit to a CCRS were estimated as $592 million using a three percent discount rate and $307 million using a seven percent discount rate. The present value of lifetime benefits of entrainment and impingement reductions over the remaining lifetime of the facility ranged from $126,219 and $207,579 with 3 percent discount rate, and $55,053 and $90,539 with 7 percent discount rate, depending on study year.

Based on the CCRS retrofit analysis the compliance and social costs far outweigh the benefits of entrainment and impingement reductions at the LEC. Retrofitting the LEC with CCRS would therefore result in social costs not justified by the social benefits making a CCRS retrofit an inappropriate option at the LEC.

1.4.5.2 Installation and Operation of TWS with 0.5 mm Fine Mesh in an Expanded CWIS

Key Document Section(s): The *§ 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study* submittal report – Sections 4 and 6, and *§ 122.21(r)(12) Non-Water Quality Environmental and Other Impacts Study* submittal report – Section 4

The fine-mesh evaluation concluded that in order to install 0.5 mm fine mesh TWSs and provide the plant with sufficient CWS flow, the CWIS must be expanded to provide greater gross screen surface area. The theoretical overall design includes 14 new 12-foot-wide screen bays to accommodate the flow and velocity requirements. The total length of the new intake would be approximately 420 feet long. Construction of such an expansion to the CWIS would require substantial site work and environmental reviews. The current design proposes to extend the CWIS by 125 feet upstream and 125 feet downstream from the current structure boundaries. It will also extend approximately 17 feet further into the river [see Section 6.2 of the (r)(10 report and Section 4.2 of the (r)(12) report]. As such, the expansion would entail impacts to riparian zones and instream habitats and would require extensive environmental reviews and permitting in conjunction with Sections 401/402/404 of the CWA, Section 10 of the Rivers and Harbors Act, Section 106 of the National Historic Preservation Act, and Section 7 of the Endangered Species Act.

A fish handling and return system would be installed for all bays. The estimated capital cost to install modified 0.5 mm fine-mesh TWS with a fish return system is approximately $49 million. The estimated annual O&M cost for modified fine-mesh TWS is approximately $0.5 million. The present value of social costs to install and operate modified 0.5 mm mesh fine-mesh TWS were estimated to be approximately $40 million using a three percent discount rate and $22 million using a seven percent discount rate. The present value of lifetime benefits of entrainment and impingement reductions over the remaining lifetime of the facility ranged from $44,691 and $73,765 with 3 percent discount rate and $19,493 and $32,174 with 7 percent discount rate depending on study year.

Based on the analysis of modified 0.5 mm fine-mesh TWS with an expanded CWIS the estimated capital, O&M, and social costs far outweigh the benefits of entrainment and impingement reductions at the LEC. Installation of 0.5 mm thru-flow modified fine-mesh TWSs at the LEC would therefore result in negative social costs making this technology inappropriate at the LEC.

[7] A hypothetical 30-year plant life expectancy was used to evaluate the costs of each CWIS technological option. Use of this conservatively long life expectancy causes annualized cost values to be underestimated and any corresponding benefits to be overestimated. Despite this, the costs of the technologies still far outweigh the corresponding benefits delineated in the associated 40 CFR § 122.21(r)(11) report.

1.4.5.3 Installation and Operation of Dual-Flow TWS with 2 mm Fine Mesh

Key Document Section(s): The *§ 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study* submittal report – Sections 4 and 6.

Preliminary analysis of available screen alternatives indicates that it may be possible to install modified (fish friendly) dual-flow conversion screens 2 mm fine mesh in the existing CWIS and increase screen surface area by an additional 20-30% which would be the minimum need to maintain the current flow-rate and through screen velocity. The installation of dual-flow conversion TWSs is considered conceptually feasible and would provide sufficient cooling water flow and through-screen velocity to sustain current plant operations. However, further analysis would be required to determine the extent of additional screen surface area that could be provided and verify that current plant operations could be maintained. The estimated capital cost to install modified dual-flow TWS with 2 mm fine mesh with a fish return system is approximately $20 million with annual O&M costs estimated at approximately $280,000. The present value of social costs to install and operate modified dual-flow 2 mm fine-mesh TWS were estimated to be $16 million using a three percent discount rate and $9 million using a seven percent discount rate. The present value of lifetime benefits of entrainment and impingement reductions over the remaining lifetime of the facility, excluding Asian carps, ranged from $41,991 and $70,225 with 3 percent discount rate and $18,315 and $30,630 with 7 percent discount rate depending on study year.

Based on the analysis of modified dual-flow 2 mm fine-mesh TWS the estimated social costs outweigh the benefits of entrainment and impingement reductions at the LEC and therefore creates a negative social cost balance (Figure 1-4). Additionally, there are two factors that weigh importantly in the evaluation of this technology. First, while 2 mm fine mesh screens are more cost-effective than 0.5 mm screens (which have been shown to have costs that far outweigh the benefits of entrainment and impingement reductions at the LEC), they lack effectiveness in excluding larvae and eggs and thereby reducing entrainment (Table 1-4).

Table 1-4 Comparison of Overall Effectiveness and Survival on Coarse and Fine Mesh Screens Based on 2015 and 2016 Entrainment Data at LEC

Target Species	Entrainment Composition (in millions)‡	Percent of Total Catch	3/8" Coarse Mesh	2.0 mm Fine Mesh	
			Exclusion Effectiveness*	Exclusion Effectiveness*	Convert Survival† (in millions)
Minnows	181.69 - 219.61	52.50 - 68.80	Very Low (0%)	Very Low (0%)	0
Gizzard shad	11.89 - 105.21	3.72 - 30.40	Very Low (0%)	Very Low (<5%)	0.52 - 2.95
Freshwater drum	58.61 - 87.63	16.94 - 27.45	Very Low (0%)	Very Low (<2%)	0.42 - 0.66
Channel catfish	0.09 - 0.57	0.03 - 0.16	Very Low (0%)	Moderate (65-78%)	0.08 - 0.37
Totals	**319.22 - 346.08**	**100.00**	**Very Low (0%)**	**Very Low (<1%)**	**1.01 - 3.98**

* Exclusion Effectiveness = percent of individuals excluded from entrainment that survive
† Convert Survival = number of individuals (previously entrained) that survival impingement
‡ Entrainment composition excluding the collection of Asian carp

Second, there is uncertainty in the ability to successfully install and operate 2 mm mesh dual-flow traveling screens at LEC. An element of that uncertainty would include the impingement and entrainment benefits that may actually be realized with the use of dual-flow screens (see Section 6.1 of (r)(10) report). The intent would be to increase screen surface area to the extent possible. This would attempt to keep through-screen velocity as low as possible. However, there will be an upper boundary to that potential given the physical configuration of the CWIS. In addition, the flow dynamics of dual-flow screens are far more complex than those of thru-flow. In a dual-flow arrangement, the water in the intake channel is forced to split around the screen's nose cone and forced into relatively narrow side channels to get to the screens. The velocity in these side channels is expected to be quite high relative to the actual through-screen velocity. Screen manufacturers have claimed that research regarding the shape of the nose cone has helped to develop near laminar flow through the screens. At LEC the presence of the two stop gates further complicates the flow characteristics. If this technology alternative were to be selected it would require a detailed analysis of hydraulic conditions within the CWIS to further evaluate flow characteristics in the forebay and through screen velocity distributions across the face of the dual flow screen. This analysis could include computer-based hydraulic modeling or physical modeling. It is conceivable that the actual through-screen velocity would increase even though there is an increase in available screen surface area. Alternatively, such modeling may demonstrate that through-screen velocity is not uniform across the face of the screen and that substantial areas may experience elevated through screen velocities. As such, it may not be possible to maintain tolerable through-screen velocity rates. Consequently, impingement and entrainment benefits could actually decrease because through-screen velocity is such an important factor for survivability of impinged and excluded individuals at the LEC. Detailed analysis and modeling are expected to take six to twelve months to complete. It is not until the end of that period would it be possible to fully assess the effect on impingement and entrainment benefits.

In consideration of all of these factors, installation of 2.0 mm dual-flow modified fine-mesh TWS at LEC is considered to have a relatively low degree of effectiveness and uncertain feasibility as it relates to through screen velocities and larval survival. The high risk and uncertainty coupled with the high social cost and low social benefit associated with 2.0 mm dual-flow modified fine-mesh make technology an inappropriate as an entrainment BTA for the LEC.

1.4.6 Conclusion

As recognized by EPA in its Section 316 regulations, the evaluation of the net social benefit of a potential activity is an appropriate mechanism to evaluate alternatives for entrainment reduction. Under the Rule, the MDNR can "reject otherwise available entrainment controls if the costs of the controls are not justified by their associated benefits (taking into account monetized, quantified, and qualitative benefits), and the other factors discussed in the final Rule." In the event the net social benefits of a proposed set of activities are negative (i.e., social costs outweigh social benefits such that expenditures to install and operate the measure do not result in a commensurate social benefit), there is no reasonable justification for that activity to represent entrainment BTA and doing so is expected to leave society worse off.

Based on the high social costs and low social benefits documented in the § 122.21(r)(9) through (12) submittal reports for closed-cycle cooling, thru-flow 0.5 mm modified TWS, and modified dual-flow 2 mm TWS, the estimated social costs outweigh the social benefits of entrainment and impingement reductions at the LEC. Further, the stated concern about the substantial uncertainty regarding the successful implementation of the dual flow 2 mm TWS at the LEC is another important factor in making this an inappropriate entrainment reduction technology at the LEC. Selection of any of these technologies to meet entrainment BTA at the LEC would result in social costs which are not justified by the social benefits. Considering that each of the candidate entrainment measures results in negative net social benefits, Ameren respectfully suggests that none of the measures is justified as entrainment BTA on a BPJ basis, and that the existing technologies and operational measures at the LEC are BTA for entrainment.

1.5 REFERENCES

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2. 40 CFR 122.21(r)(2) – SOURCE WATER PHYSICAL DATA

This section presents the available data on the physical characteristics of the source water body on which the LEC CWIS withdraws cooling water.

2.1 LOWER MISSOURI RIVER

The LEC is located on the south bank of the LMOR, approximately 57.5 river miles west of the confluence of the Mississippi River along a low-lying floodplain area of the river generally known as Labadie Bottoms (Figure 1-1 and Figure 2-1). Labadie Bottoms comprises about 10 square miles of farmland and wetlands in the Missouri River floodplain, situated immediately south of the Missouri River. The river has a width of approximately 1,300 feet in the Labadie Bottoms area, and meanders within a broad, 2-mile wide floodplain bounded by steep bluffs that can be more than 300 feet high. Labadie Bottoms is underlain by soft alluvial sediments with a thickness of about 110 feet, situated above Ordovician dolostone and sandstone units. The alluvial aquifer is highly permeable, and the water table adjusts to be within about ±10 feet of the fluctuating river level (USGS 2010). Labadie Bottoms is protected from moderate flooding by a non-federal, agricultural levee with a crest El. of about 480 feet above MSL (Ameren 2009). A large portion of Labadie Bottoms is situated within the FEMA 100-year regulatory floodplain (FEMA 1984), and flooding of the general area has occurred on numerous occasions.

2.2 MISSOURI RIVER MANAGEMENT PROGRAMS

The LMOR has been altered in both its channel form and flow regime by channelization and upstream dams (Johnson et al. 2006). Flow regulation began on the Missouri River in the late 1930s and was completed with the closure of the Missouri River Reservoir System in 1954 (Ferrell 1993; Galat and Lipkin 2000; Jacobson and Heuser 2001). The system is managed for multiple purposes, including maintenance of commercial navigation flows, flood control, hydropower, public water supply, recreation, and fish and wildlife resources. The U.S. Army Corps of Engineers (USACE) Northwestern Division, Kansas City District, is responsible for maintenance of the federal navigation channel. The USACE Civil Works Division manages 500 miles of the Missouri River, including projects related to habitat restoration and recovery programs, recreation, flood risk management, navigation, riverbed degradation, and dam and levee safety. USACE also reviews and issues permits for commercial dredging operations under the Rivers and Harbors Act and the Clean Water Act to dredge sand and gravel from the Missouri River below Rulo, Nebraska.

Channel modifications in the LMOR began in the early 1800s with clearing and snagging to improve conditions for steamboat navigation (Chittenden 1903). The current channel morphology is dominated by rock wing dikes and revetments constructed as part of the Missouri River Bank Stabilization and Navigation Project (Figure 2-2; Ferrell 1996). These structures stabilized the banks and narrowed and focused the river geometry to help maintain the navigation channel from St. Louis, Missouri to approximately 750 miles upstream at Sioux City, Iowa. The rock structures and revetments (outside of bends) and dikes (inside of bends) force the river into a channel alignment that is self-maintaining.

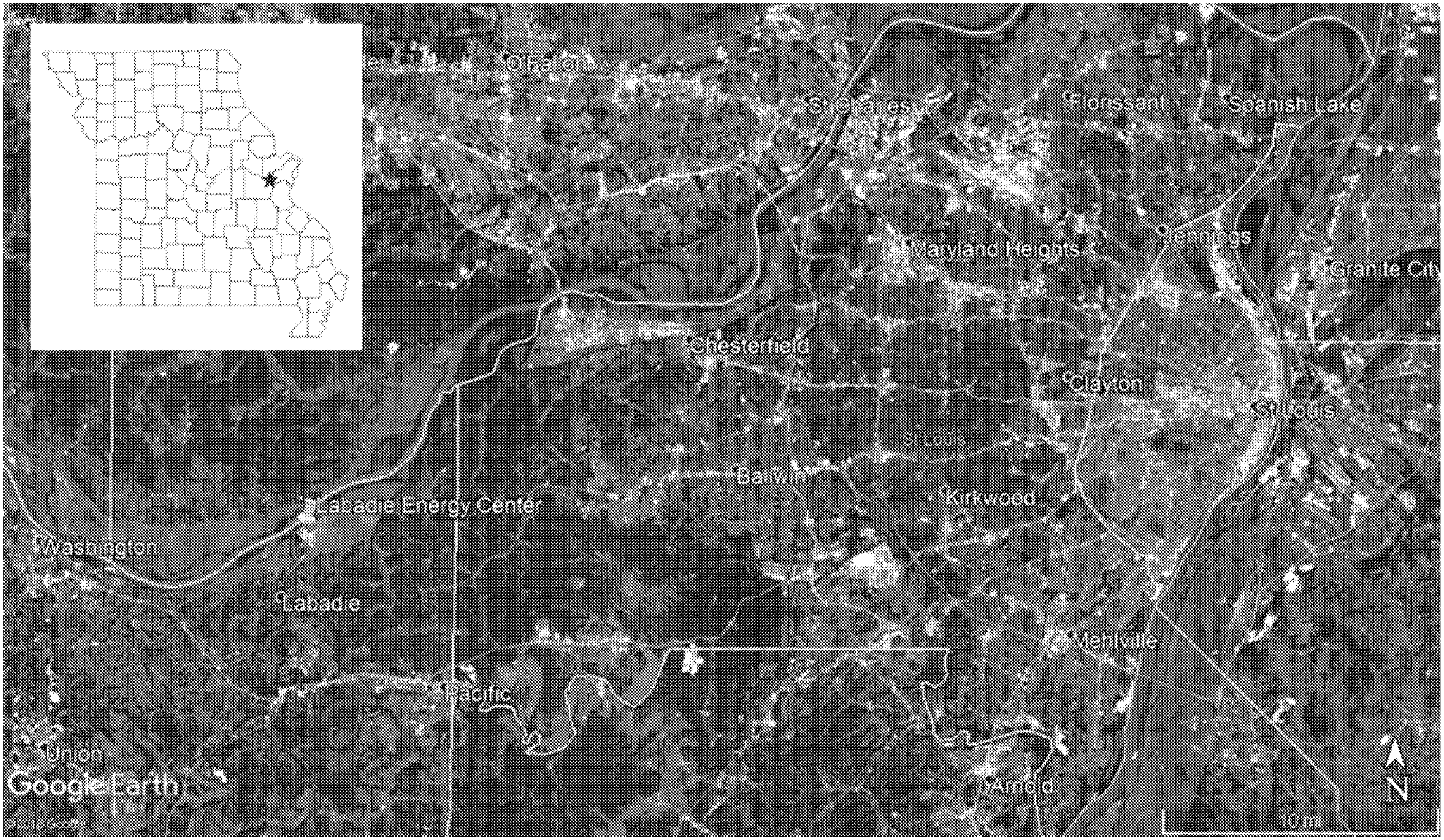


Figure 2-1 Location of the Ameren LEC, Franklin County, Missouri.

Figure 2-2 Wing and L-Dikes Downstream of LEC.

Approximately 10,000 acres of riverine habitat within the LMOR are estimated to have been lost following flow and channel modifications (Funk and Robinson 1974). Reductions in ecosystem integrity associated with lost or altered habitat (Hesse and Sheets 1993) likely have contributed to the decline of several native Missouri River fishes, including the federally endangered pallid sturgeon (*Scaphirhynchus albus*) (Dryer and Sandvol 1993).

The Kansas City and Omaha Districts of the USACE, in cooperation with the U.S. Fish and Wildlife Service (USFWS), developed a Draft Missouri River Recovery Management Plan (MRRP) and Draft Environmental Impact Statement (EIS; USACE 2014b). Public comment on the Draft EIS concluded on 24 April 2017. The MRRP is an effort to replace lost habitat and avoid a finding of jeopardy to T&E species resulting from USACE projects on the Missouri River related to operation of the mainstem river reservoir system, ongoing navigation, and bank stabilization. The EIS is a programmatic assessment of actions necessary to comply with the Endangered Species Act (ESA) by avoiding a finding of jeopardy to three federally-listed T&E species associated with the Missouri River: pallid sturgeon, interior least tern (*Sterna antillarum athalassos*), and the Northern Great Plains piping plover (*Charadrius melodus*).

Some of the restoration aspects of the program include development of emergent sandbar habitat, shallow water habitat, and wetland and terrestrial habitat. The program also includes ongoing data collection and monitoring to determine if these actions are effective. These actions are being taken pursuant to the 2000 Biological Opinion, amended in 2003 (USFWS 2003).

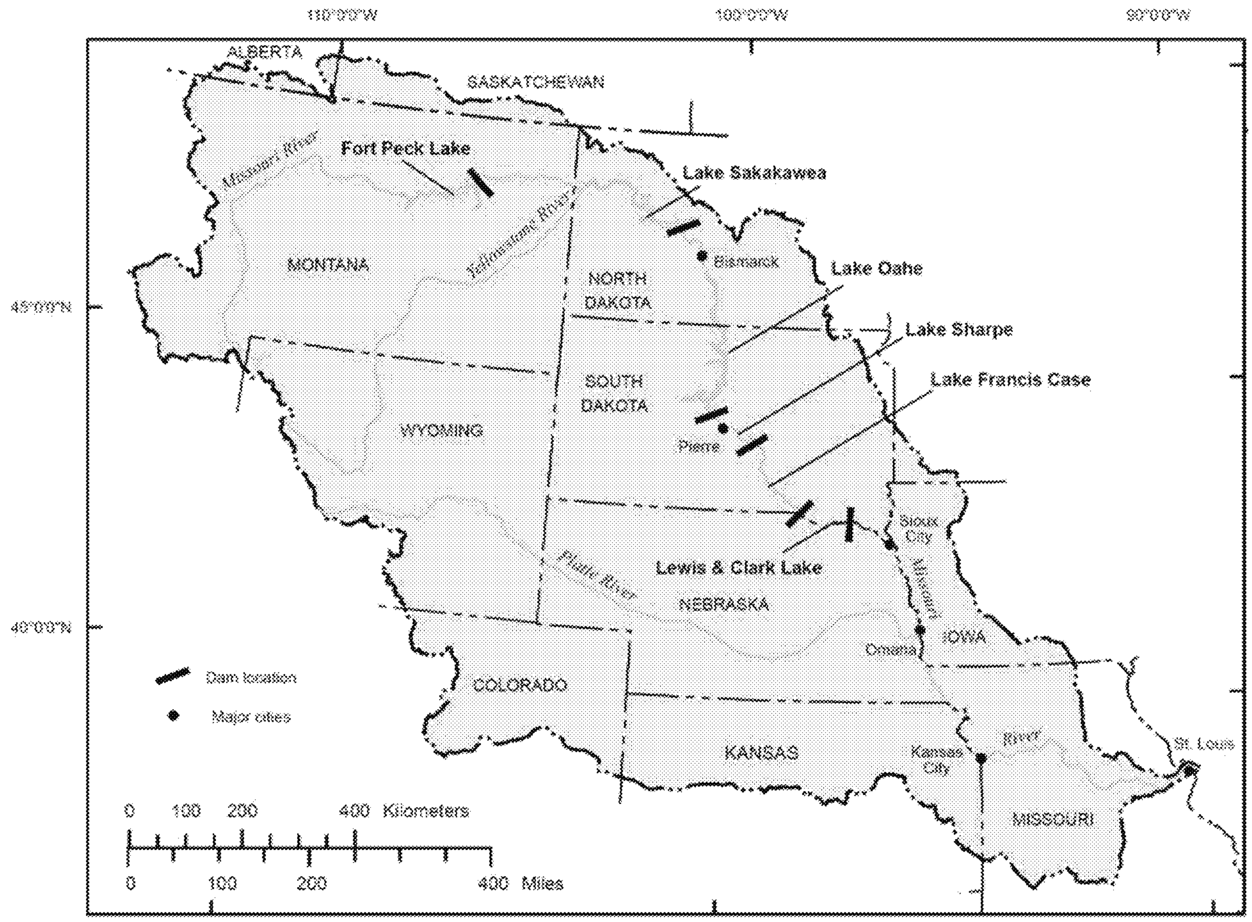
2.3 SOURCE WATER GEOMORPHOLOGY

2.3.1 Missouri River

The Missouri River is one of the major river systems in the U.S., with a 529,350 square mile drainage basin (Figure 2-3). It flows 2,341 miles from its headwaters at the confluence of the Gallatin, Madison, and Jefferson Rivers near Three Forks, Montana to its confluence with the Mississippi River at St. Louis, Missouri. Along its course, it traverses seven states, including Montana, North Dakota, South Dakota, Iowa, Nebraska, Kansas, and Missouri. The river delineates the southern and southwestern extent of Pleistocene glaciation (Spooner 2001).

The Missouri River flows from the Northern Rocky Mountain physiographic province through the glaciated Great Plains and Central Lowlands provinces, and finally through the unglaciated, limestone-dolomite Ozark Plateaus (Galat et al. 2005a, 2005b), where the LEC is located. Approximately 70 percent of the Missouri River Basin lies within the semi-arid Great Plains, so it is largely a dry-land river. The geomorphology of the river originally was the product of highly variable daily and seasonal flow rates that carried sediments from the highly erodible soils typical of the Missouri River Basin. The result was a complex, meandering river basin and flood plain that was continually shifting but nevertheless in dynamic equilibrium. The lower Missouri River and its floodplain from Glasgow, Missouri to St. Louis are largely confined by nearly vertical limestone and dolomite bluffs.

The Missouri River has changed dramatically as the result of human efforts to manage the river for navigation and flood control. Modifications to the river and its floodplain began in the late 1800s simply with removal of snags to permit navigation (NRC 2002). Channel enhancements began in the early 1900s and damming and flow regulation began in the 1930s. The river modifications culminated in the construction of six USACE dams on the upper mainstem of the river in the 1950s and 1960s and the completion of the Missouri River Bank Stabilization and Navigation Project in the lower, unimpounded river in 1981.



Source: Jacobson 2008.

Figure 2-3 Missouri River Drainage Basin Map.

Dam construction and channelization along the Missouri River mainstem has fragmented the river into four types of ecological units: a free-flowing reach upstream of the reservoirs, the reservoirs, remnant floodplains between the reservoirs, and a channelized reach below the most downstream reservoir (NRC 2002). Downstream of the lowermost dam, Gavins Point, there is an unchannelized reach extending 77 miles to just upstream of Sioux City, Iowa (Figure 2-3). The channelized reach then begins and runs 735 miles to St. Louis, or about one-third of the total length of the Missouri River. Reservoirs on the upper river system consists of six dam and reservoir (lake) projects. The USACE constructed, operates, and maintains these projects to serve congressionally-authorized project purposes of flood control, navigation, irrigation, hydropower, water supply, water quality, recreation, and fish and wildlife. The reservoir system has the capacity to store 72.4 million acre-feet (MAF) of water, which makes it the largest reservoir system in North America. To achieve these multipurpose benefits, the system is operated in a hydrologically and electrically integrated manner (USACE 2016c).

The combined storage capacity of all six mainstem reservoirs is about three times the annual runoff in the basin above Sioux City, Iowa. The storage capacity of the system and each reservoir is divided into four storage zones for regulation purposes. The operation of the system is guided by the Missouri River Master Water Control Manual (Master Manual) (USACE 2006). This Master Manual records the basic water control plan and objectives for the integrated operation of the mainstem reservoirs. The reservoir stage and flow releases vary throughout the year as a result of reservoir operations that follow the Master Manual (USACE 2016c).

Total annual runoff from the Missouri River varies considerably from year to year because of large variations in precipitation. Annual runoff, as measured above Sioux City with adjustments for depletions, varied from 11 MAF to 61 MAF between 1898 and 2015. The median runoff at Sioux City is 25 MAF. About 29 percent of this runoff enters above Fort Peck Dam, 42 percent between Fort Peck and Garrison Dams, 10 percent between Garrison and Oahe Dams, 3 percent between Oahe and Fort Randall Dams, 7 percent between Fort Randall and Gavins Point Dams, and 9 percent between Gavins Point and Sioux City. Any runoff below Gavins Point Dam is not influenced by the Missouri River Mainstem Reservoir System (USACE 2016c).

Runoff in the lower river (from Sioux City to St. Louis) averages about 43 MAF (1967 through 2014), which accounts for 63 percent of the runoff in the basin. The most notable periods of drought were 1930 to 1941, 1954 to 1961, 1987 to 1992, and 2000 to 2007. The 1987 to 1992 drought ended with the "Great Flood of 1993" in the summer and fall of that year. The wet period following the drought in the 2000s included the record flood of 2011. Climate, upstream tributary depletions, and construction of reservoirs on the mainstem and tributaries affect runoff upstream of Sioux City. Depletions and evaporation from large reservoirs reduce runoff from the basin. Depletions are likely to increase in the future, further reducing average annual basin runoff (USACE 2004; USACE 2016b). Groundwater and surface water evaporate in warm weather periods, primarily from April through October (USACE 2006). The average annual evaporation rate in the reservoirs of the Missouri River basin is less than 2 feet in the western Rocky Mountains and more than 6 feet in the plains area of western Kansas. Evaporation from the mainstem reservoirs averages 3 feet annually (USACE 2016c).

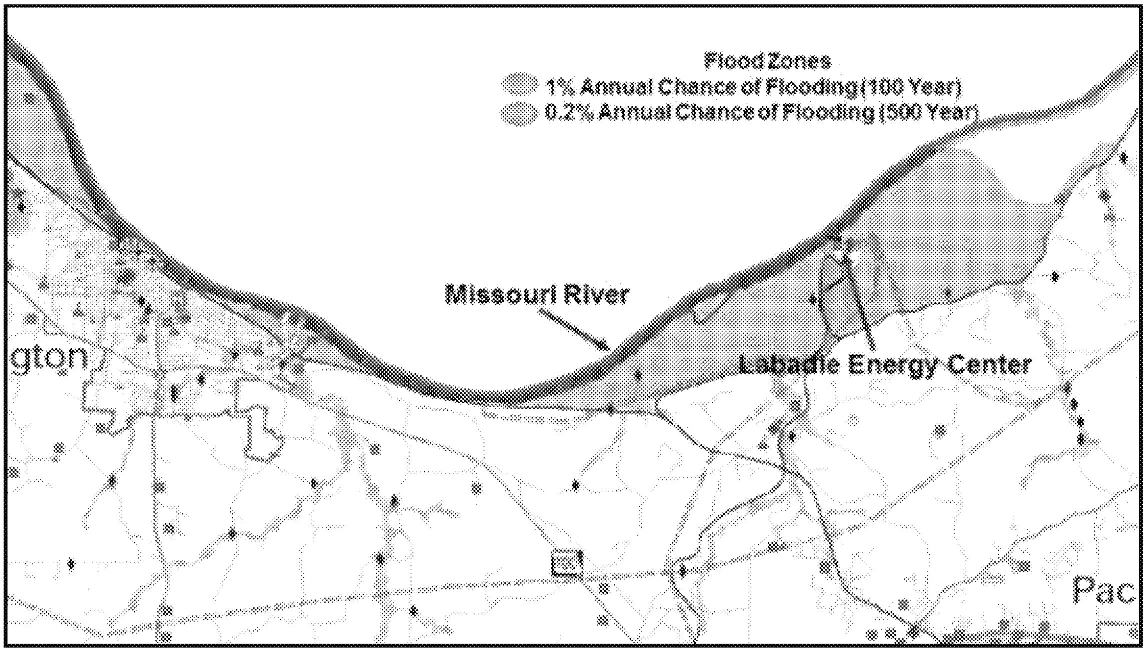
2.3.2 Lower Missouri River

LEC is located within the channelized reach of the lower river which has been significantly altered. This reach of the river has been straightened, deepened, and narrowed by the construction of revetments and dikes, and by dredging to maintain a 300-foot wide navigation channel that is at least 9 feet deep. The LMOR ranges from approximately 600 to 1,300 feet wide and the channel now is narrower and more uniform than its previous form, with a trapezoidal cross-section resulting in steeper embankments and faster currents. River meanders have been straightened, natural riparian vegetation has been lost, variations in river flows and water temperatures have been reduced, periodic overbank flow to the floodplains and its nutrient cycling benefits have been eliminated or reduced, sediment transport has been reduced, and natural processes of cut and fill alleviation have been modified. A large percentage (>50 percent) of the river's floodplain is in intensive agriculture (Angradi et al. 2011). Land use within approximately 3 miles of the river is primarily cropland (33 percent) and grassland (26 percent), with 17 percent under development (Revenga et al. 1998, Galat et al. 2005a).

The amount of natural aquatic habitat has been greatly reduced, thus reducing the abundance of native species and affecting the composition of the fish community. It has been estimated that approximately 3 million acres of riverine and floodplain area have been lost as the result of channel straightening and levee construction (NRC 2002). Lost also are the flood pulses in the spring and early summer that influenced the river morphology, connected side channels and backwaters to the main channel, created new and productive habitats, cycled organic material and nutrients between the channel and floodplain, replenished water in the floodplain, and served as cues for spawning of fish and other organisms. Productive side channels, chutes, sand bars, islands and backwaters are much reduced. To mitigate the loss of riverine habitat and the natural flow regime, the USACE instituted the MRRP (USACE 2016c), the aims of which previously were summarized in Section 2.2.

In the LMOR, sand is the dominant substrate in the main channel, comprising 81 percent of the sediments (Galat et al. 2005a). Silt averages less than 10 percent but is the dominant substrate material in non-connected secondary channels and tributary confluences. Coarse sediment particles such as sand are transported by river currents close to the channel bed, whereas finer particles such as silt are transported higher in the water column and can be carried out of the river channel to the floodplain, chutes, or other off-channel water bodies (NRC 2011). Fine suspended particles carried downstream in the Mississippi River and its tributaries, including the Missouri River, dominate the formation and maintenance of coastal wetlands in and along the lower Mississippi River and its delta in the Gulf of Mexico. Coarser sedimentary particle load helps to shape the channel morphology, including sand bars within the lower river.

The LEC lies on the south bank of the lower Missouri River. Figure 2-4 shows the alignment of the river channel within the floodplain near LEC and the corresponding 100- and 500-year flood zones. Figure 2-5 shows the location of the federal navigation channel as well as major floodwater levees in the vicinity of the LEC (USACE 2014a). The south bank of the river has been reinforced with rip-rap and revetments. The river bottom drops sharply because the channel closely approaches the south bank in this area. On the north bank and downstream from the LEC on the south bank rock pile dikes extend into the river. Sandy beaches are exposed at low water levels. The river currents past the LEC are swift, with velocities estimated between 2.6 and 4.8 feet per second. There is no rooted vegetation and the substrate consists of rock, stone or gravel in areas of current, and silt or clay in depositional areas.



Source: East-West Gateway Council of Governments 2010.

Figure 2-4 FEMA Mapped Flood Zones in LEC Vicinity.

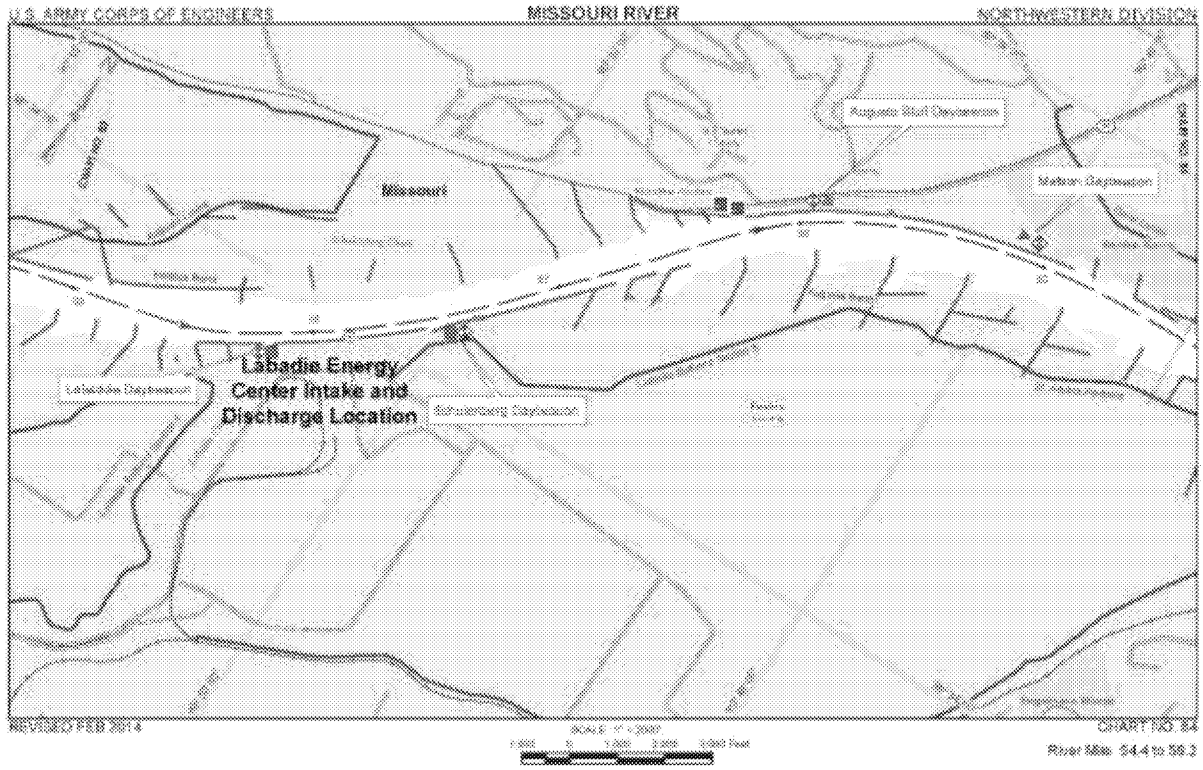
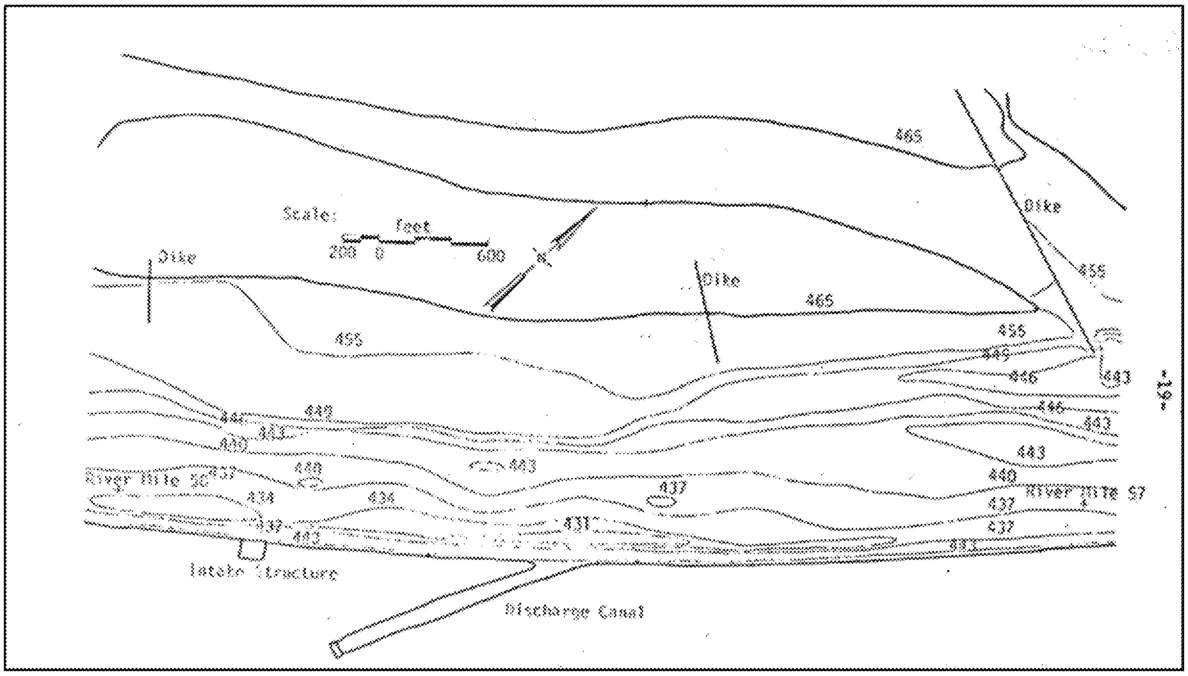


Figure 2-5 USACE Navigation Chart and Levee System in LEC Vicinity.

The Missouri River is approximately 1,300 feet wide and has an approximate average depth in the range of 16 feet in the vicinity of the LEC CWIS and discharge canal (UEC 1976). The water depth and width of the river within a given reach can vary according to discharge from the upstream dams and location within the channel. The Missouri River's water surface El. at LEC, and consequently its width, depth, and cross-sectional area, are influenced by the USACE operation of the large upstream, mainstem reservoirs. Along the Lower Missouri River there are numerous wing dikes, such as downstream of the LEC discharge canal, that have been constructed along the shoreline to improve and maintain the navigability of the river (Figure 2-5). The river's water surface El. varies with flow in the river. As flow increases, depth of flow increases and, hence, the water surface El. increases.

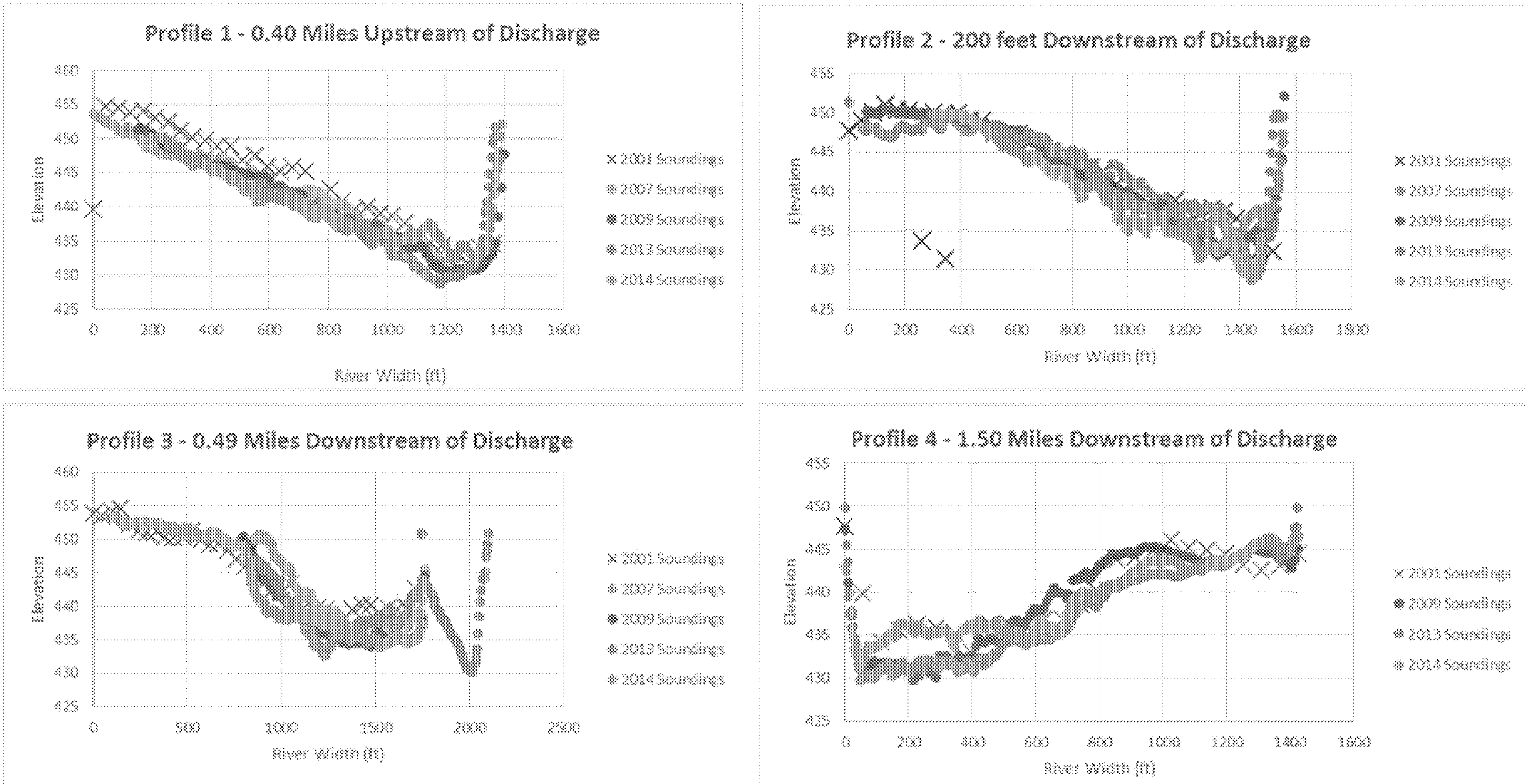
Historic bathymetry data at LEC (Figure 2-6) show that the deepest area is near the south bank of the river adjacent to the opening of the discharge canal (RM 57.5). Within this area, the river bottom has an El. of approximately 430 feet above MSL. At the opening to the CWIS (RM 57.8), the river bottom has an El. of approximately 435 feet above MSL (UEC 1976). According to the LEC § 316(a) demonstration (UEC 1976), the river bottom is relatively uniform downstream of the discharge canal and has no abrupt or significant changes.



Source: UEC 1976.

Figure 2-6 Bottom Contour of the Missouri River at LEC (El. in ft above MSL).

More recent bathymetric information for the river near the LEC was available from depth measurement sounding surveys conducted by USACE in 2001, 2007, 2009, 2013 and 2014. LEC has been recording water surface El. at its intake structure since January 2000 (Kleinfelder 2016). Depth sounding surveys from 2001 to 2014 in the vicinity of LEC indicated that the shape of the river bottom changes somewhat with time. Erosion of the river bottom during high flows and subsequent deposition during low flows can cause changes in the local cross-sectional configuration along the river (Kleinfelder 2016). Depth sounding profiles of the river bottom upstream and downstream of the LEC discharge channel are shown in Figure 2-7 (Kleinfelder (2016).



Source: Kleinfelder 2016.

Figure 2-7 Comparison of River Depth Soundings at LEC.

2.4 HYDROLOGY AND COOLING WATER WITHDRAWAL

2.4.1 Missouri River Hydrology

As authorized by the Flood Control Act of 1944, flow in the Missouri River is regulated according to the Missouri River Main Stem Reservoir System Regulation Manual (better known as the Master Manual). The Master Manual (USACE 2006) is supplemented by an Annual Operating Plan, which is interpreted and administered by the Reservoir Control Center of the USACE Northwest Division in Omaha, Nebraska. The Master Manual was revised in 2004, resulting from and greatly influenced by a severe drought extending from 1988 to 1992, which mobilized the attention of multiple river use stakeholders with interests in upstream recreation; protection of three T&E species (least tern, piping plover, and pallid sturgeon) and other valuable natural and historical/cultural resources; downstream navigation; irrigation; and other vital water uses including cooling water for steam generating power plants. Revisions to the Master Manual were completed under the National Environmental Protection Act and involved preparation of an EIS and consultation with the USFWS under the ESA.

The typical annual flow cycle in the regulated Missouri River involves peak reservoir storage in July, followed by a gradual decline in storage until late winter (USACE 2006). There are two natural peak river flows: one in late February to April created by snowmelt and rainfall in the plains and a second one in May to July created by snowmelt and rainfall in the mountains. River flow in the channelized reach is further supplemented and modulated by tributary inflow. Flow releases are adjusted according to short-term and annual rainfall amounts and resulting water storage, as well as nesting requirements for the two T&E bird species (least tern and piping plover) on the storage reservoirs. Targeted flow releases are increased for the navigation period, which normally begins by April 1 near St. Louis and extends until early December.

USACE can regulate flows from the Gavins Point Dam to mitigate flooding of areas downstream of the dam due to seasonal runoff and storm events. Flood risk reduction is a primary consideration along the river. Heavy rainfall events throughout the basin can cause localized flooding downstream of the reservoir system. USACE continuously monitors basin conditions, including rainfall and mountain snow accumulation, and adjusts the regulation of the reservoir system based on current information (USACE 2006).

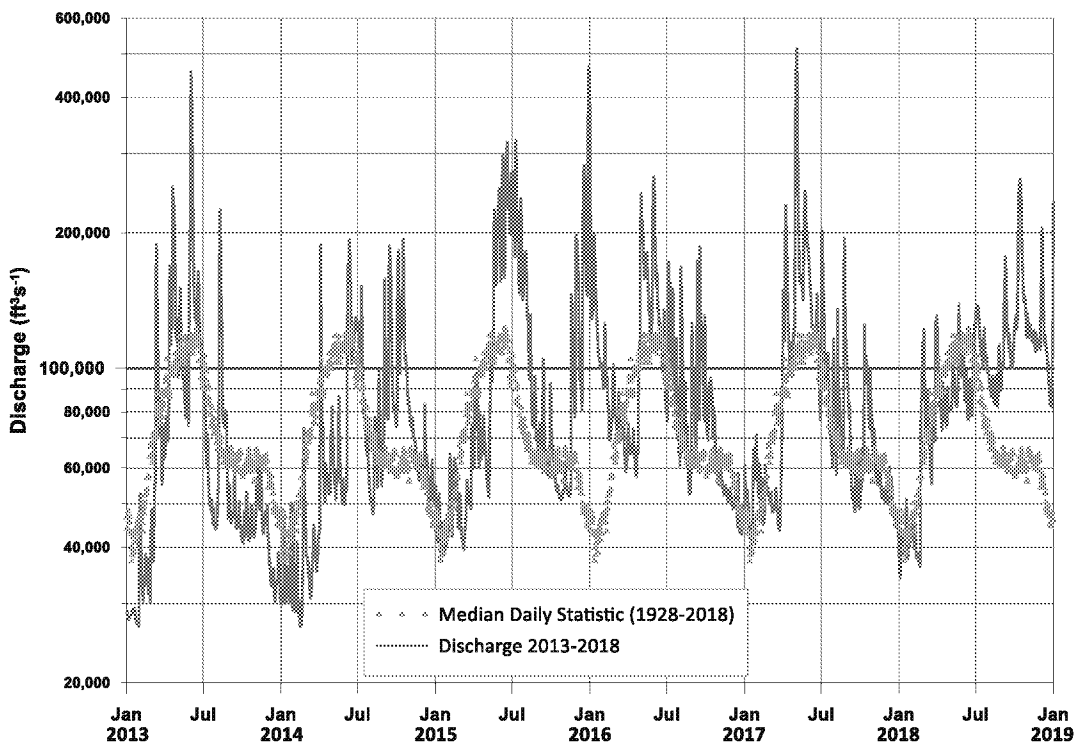
In April 2017, releases from the Gavins Point Dam averaged 28,500 cfs. In early May 2017, the USACE Missouri River Basin Water Management Division reduced releases from Gavins Point. Prior to this action, downstream Missouri River and tributary flows increased due to widespread, heavy rainfall in parts of Nebraska, Kansas, and Missouri. USACE noted that Gavins Point releases were reduced from 30,000 cfs to 21,000 cfs over several days to lessen downstream flooding. Releases from Gavins Point were increased as downstream flows receded (USACE 2017).

During the last 20 years, an increase in the frequency and severity of floods and droughts has been observed. Record floods were recorded in the LMOR in 1993 and 2011 (NOAA 2013). The 1993 flood was considered to be a 100-year or greater flood, when river discharge at the United States Geological Survey (USGS) Hermann gage peaked at 750,000 cfs. According to the USGS, widespread flooding from severe December 2015 rainfall affected large sections of the central and southern United States. Stress on the Nation's major rivers continued into 2016, as portions of the Ohio River, Missouri River, and Mississippi River threatened to match or exceed 2011 levels (USGS 2017a).

Rising flood stages imply that large floods will continue to occur more frequently. Accounting for the rising stage, the greatest flood (1993) in the 72-year record would be only the fourth greatest flood, with a recurrence of only 15-20 years (Pinter and Heine 2001). The increasing trend in flood stage has been attributed to the constriction of the channel, caused by wing dams and levees, resulting in a smaller cross-sectional area of flow, and by lower flow velocity (Pinter and Heine 2001). The combined effects of flooding and dredging have contributed to riverbed erosion and subsequently reduced river access, especially during droughts. Low flow conditions in the lower river can be detrimental in terms of meeting NPDES permit conditions, especially in terms of thermal effluent limitations (FAPRI 2004).

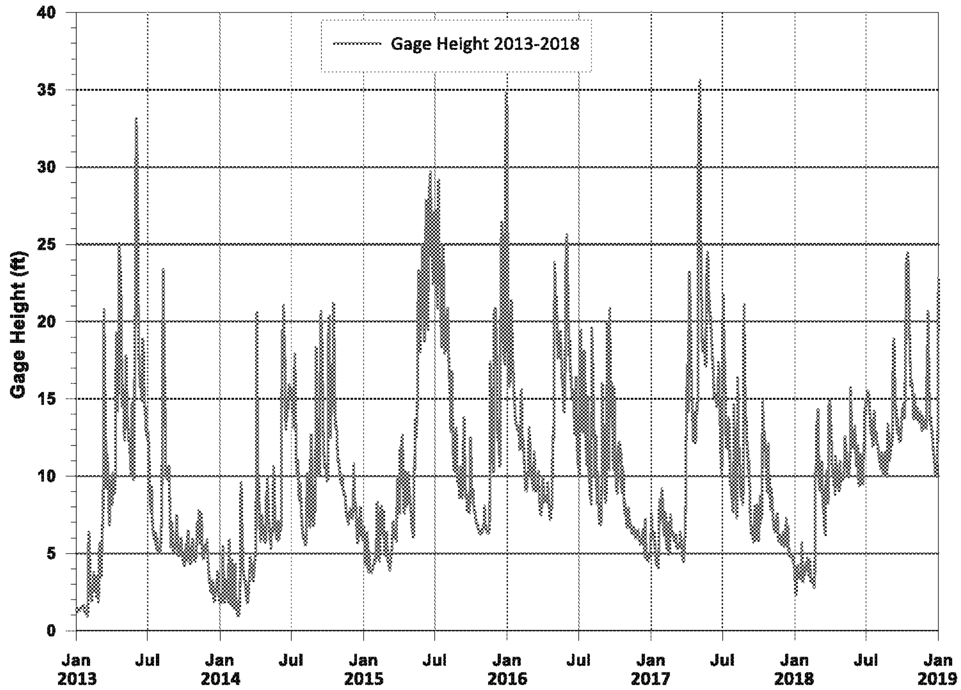
A hydrograph is presented in Figure 2-8, based on observed flows for the last 6 years of available data (2013-2018) measured at USGS Gage number 06934500 located at Hermann, MO, about 37 miles upstream of the LEC CWIS. Table 2 A-3 (Appendix 2 A) presents monthly mean flow data (cfs) for the period of 1928 to 2018 for the Hermann gage. Figure 2-9 presents the gage height in feet measured at the Hermann station from 2013-2018. Gage height, which is also known as stage, is the height of the water above a reference point for the specific pool at the gaging station. Gage height does not refer to stream depth (USGS 2011).

Figure 2-10 presents flows for the last 4.75 years of available data (April 2015 – December 2018) measured at the USGS Gage number 06935550, which is located at the LEC near the CWIS. For the same period, Figure 2-11 presents the gage height in feet and Figure 2-12 presents the water level El. in feet based on the North American Vertical Datum of 1988 (NAVD 88) at the LEC. The NAVD 88 is the vertical control datum of orthometric height established for surveying height based upon the general adjustment of the North American Datum of 1988 (Zilkoski et al. 1992).



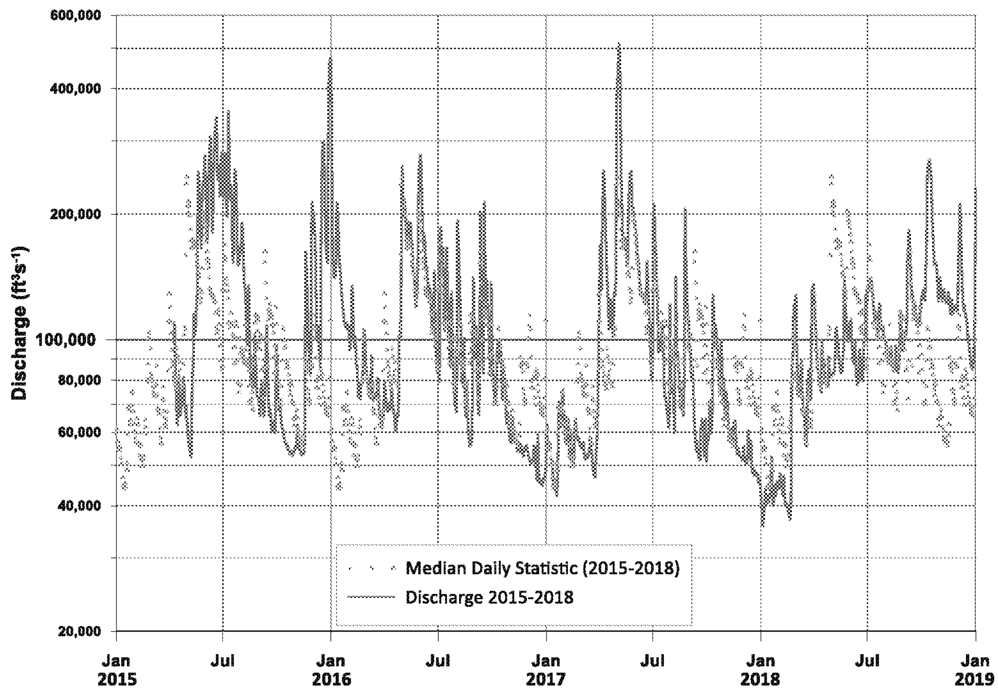
Source: USGS 2019.

Figure 2-8 Discharge (cfs) at Hermann Gage, MO.



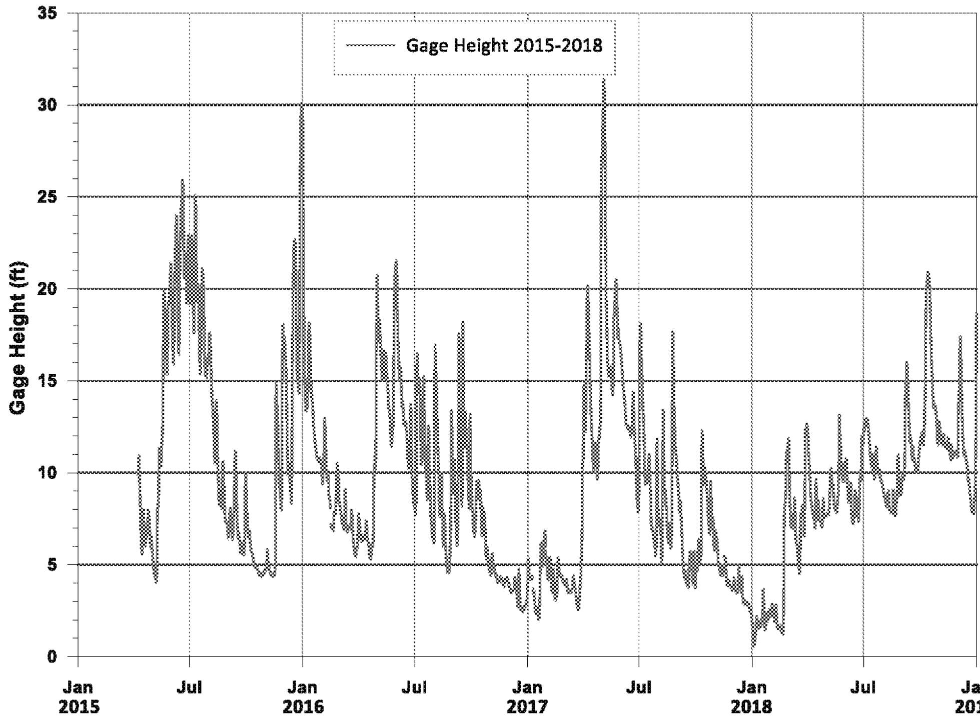
Source: USGS 2019.

Figure 2-9 Gage Height (ft) at Hermann Gage, MO.



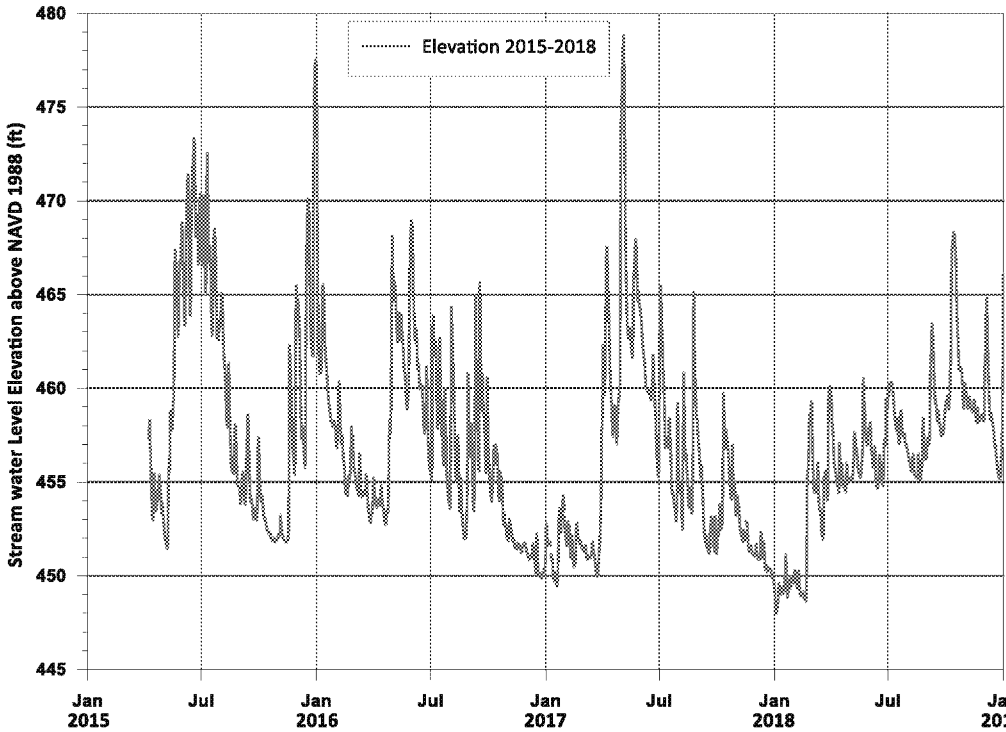
Source: USGS 2019.

Figure 2-10 Discharge (cfs) at Labadie Gage, MO.



Source: USGS 2019.

Figure 2-11 Gage Height (ft) at Labadie Gage, MO.



Source: USGS 2019.

Figure 2-12 River Water Level (ft) Above NAVD 1988 at Labadie Gage, MO.

2.4.2 Hydraulic Area of Influence

In preparing the § 122.21(r)(2) Source Water Physical Data submittal, USEPA requires that the owner or operator of the facility submit information that will provide an *"(ii) identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods you used to conduct any physical studies to determine your intake's area of influence within the waterbody and the results of such studies"*.

The area of influence (AOI) is also commonly referred to as the hydraulic zone of influence (HZI). An AOI is generally considered to be the portion of the source waterbody directly affected by the withdrawal of cooling water by the CWIS or where the natural water velocity vectors are measurably deflected toward the CWIS. In the Phase I § 316(b) Rule for new facilities USEPA described the AOI as *"the portion of water subject to the forces of the intake structure such that a particle within the area is likely to be pulled into the intake structure"*.

Ameren Missouri has not conducted any specific studies to determine the AOI for the LEC. The LEC CWIS is located on the south bank of the Missouri River shoreline on an outside bend. Due to its location on an outside bend of the river, the main channel of the river runs very close to the LEC CWIS. This area of the river is characterized by swift currents and a shifting substratum, which does not represent preferred fish habitat (MDNR 2017).

As part of a 2005-2006 Impingement Mortality Characterization and Intake Technology Review, ASA and Alden (2008) described flow in the Missouri River as highly controlled and seasonally variable. The river velocities past LEC were estimated to be between 2.6 and 4.8 fps. Based on 10 years of flow data (1997-2006) at the Hermann gage, the mean annual flow of the river was reported to be 80,979 cfs (ASA and Alden 2008).

Looking at an even longer river flow data set for the Hermann gage (1958-2017), mean annual river flow past LEC was reported to be 88,136 cfs (USGS 2017a). The LEC intake structure has a DIF of 2,240 cfs based on all 8 pumps running, and normal river El. of 455 feet. With a mean annual river flow of 88,136 cfs for the period of 1958-2017, the facility DIF represents approximately 2.5 percent of the river's mean annual flow.

Ameren-Missouri conducted entrainment characterization studies in 2015 and 2016. Ameren-Missouri believes that these entrainment studies provide sufficient site-specific data, obviating the need for a separate AOI determination to be completed as part of this § 122.21(r)(2) submittal.

2.5 WATER QUALITY

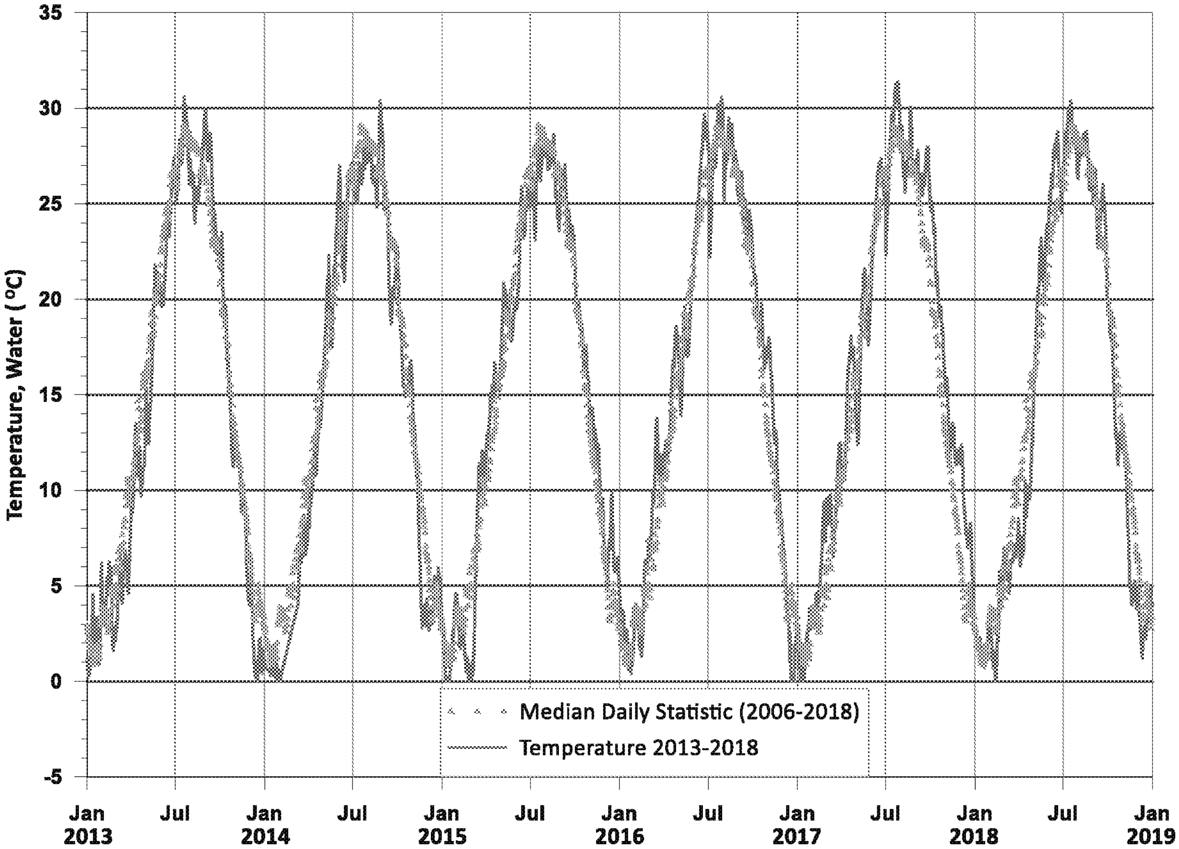
This section discusses water quality within the LMOR and the vicinity of the LEC and is organized into subsections based on commonly collected water quality parameters for which data were available.

2.5.1 Water Temperature

Water temperature within the LMOR is strongly influenced by ambient conditions. Thus, water temperatures closely track seasonal changes in air temperature with peaks occurring during mid-summer and lows during wintertime. Water temperatures typically are lower within the mainstem of the river compared to shallow shoreline areas. The vertical thermal profile in the river tends to be uniform as a result of swift currents and turbulence.

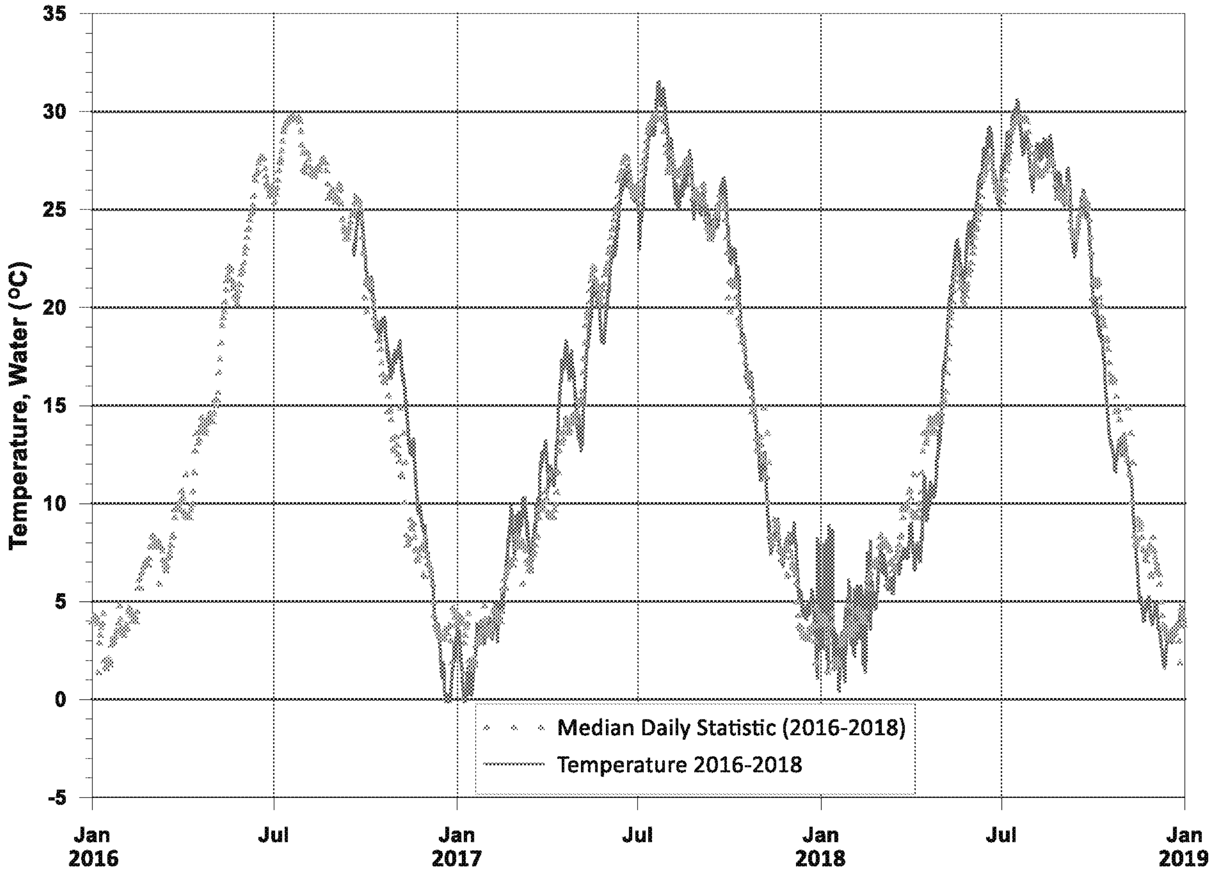
Annual mean water temperatures ranged from 58.2 °F to 62.0 °F at the USGS Hermann, MO gage from 2011 to 2018, when sampling was conducted over more than 300 days per year. Annual means from the entire period between 2006 through 2018 are reported in Table 2 A-1

(Appendix 2 A). Figure 2-13 presents daily water temperatures (°C) at the Hermann gage from 2013 to 2018, whereas Figure 2-14 displays daily water temperatures at the Labadie gage 2016 through 2018. In both cases, water temperatures showed a typical seasonal trend (i.e., mid-summer temperature peaks, winter lows) with relative consistency on an annual basis.



Source: USGS 2019.

Figure 2-13 Ambient Water Temperature at Hermann Gage, MO.



Source: USGS 2019.

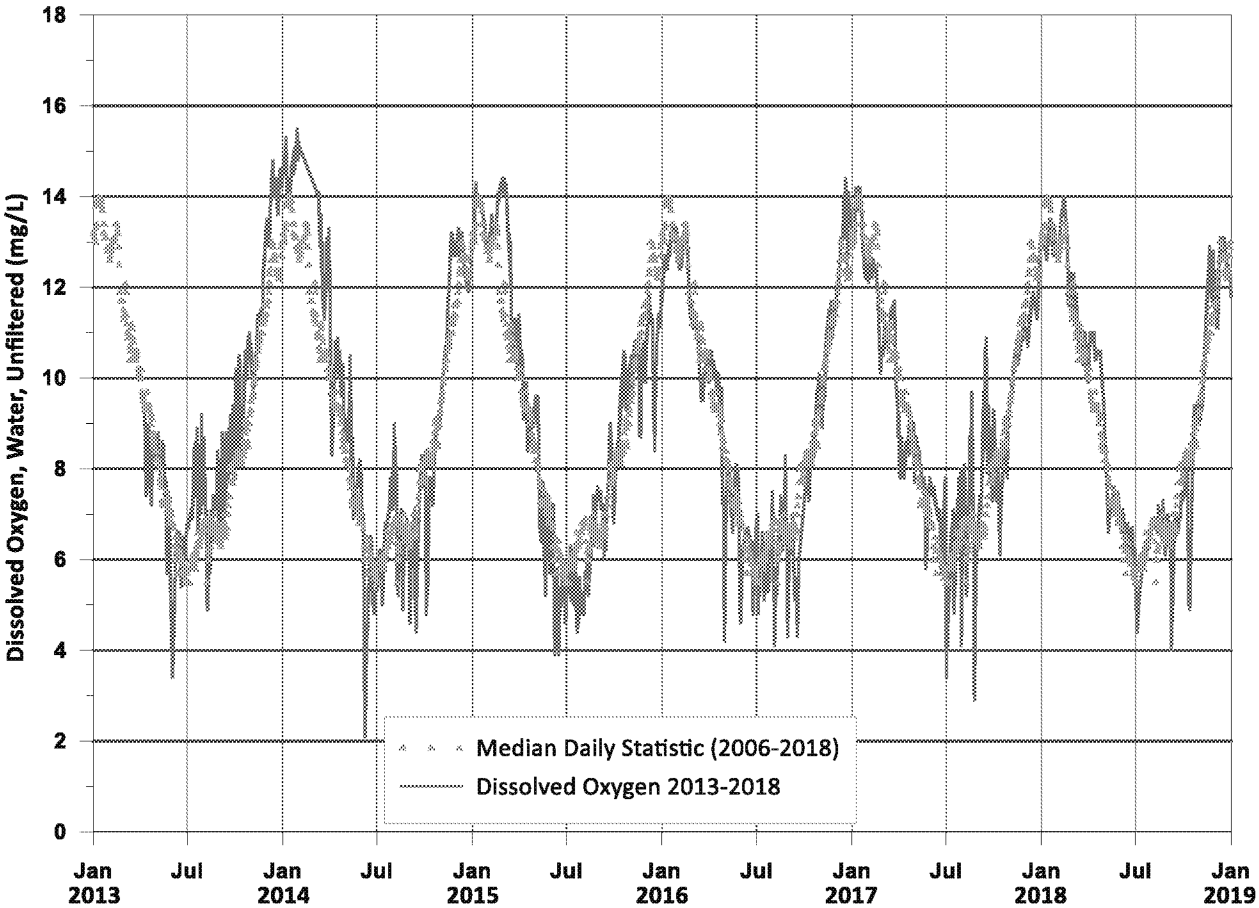
Figure 2-14 Ambient Water Temperature at Labadie Gage, MO.

2.5.2 Dissolved Oxygen

Dissolved oxygen (DO) concentrations in the LMOR are also influenced by ambient conditions. However, in contrast to water temperature, DO levels tend be lowest during warm months due to decreased oxygen solubility as well as hypolimnetic oxygen degradation during periods when the water column is thermally stratified. Additional water quality parameters, such as concentrations of nutrients and suspended materials, can further influence DO such that organic waste discharges and increased turbidity to the mainstem periodically create local zones of high biological oxygen demand that exhibit temporarily depressed DO levels in the lower river reaches (USACE 2016c).

Mean daily unfiltered DO concentrations from 2013-2018 at the USGS Hermann gage are shown in Figure 2-15. The DO concentration standard is 5 milligrams per liter (mg/L) and DO was typically below saturation levels. DO levels exhibited a typical seasonal pattern with higher concentrations in cooler months and lower concentrations during warmer, summer months. Although DO concentrations in this reach of the lower Missouri River are typically at or above 5 mg/L, levels periodically may fall below the standard when ambient river temperature are especially warm. Mean annual DO concentration at the Hermann gage ranged from 8.94 to 9.53 mg/L between 2014 and 2018, when sampling was conducted over more than 300 days per year.

Annual means from the entire period between 2006 through 2018 are reported in Table 2 A-1 (Appendix 2 A).



Source: USGS 2019.

Figure 2-15 Dissolved Oxygen Concentration (mg/L) at Hermann Gage, MO.

2.5.3 Turbidity

The suspended sediment load in a river system directly relates to water clarity and, thus, turbidity. During periods of heavy rain and snowmelt, particularly in the spring, run-off from land can carry large amounts of silt into streams and rivers. During summer, phytoplankton blooms can contribute to increased turbidity. Erosion of unprotected shorelines contributes suspended particles to the water and previously deposited finer sediment particles can become re-suspended in shallow waters due to high flows, heavy winds, or boat traffic (USACE 2016c). Turbidity can affect the density and diversity of aquatic life by limiting primary productivity, decreasing foraging effectiveness, and causing gill clogging. Conversely, species adapted to living in turbid waters can be impacted negatively following management actions that enhance water clarity (USACE 2016c).

The Missouri River was naturally very turbid, but engineering modifications completed during the 20th century resulted in four-fold decreases in turbidity from 1200-2600 to 200-400 Nephelometric Turbidity Units (NTU) between 1930 and 1983 (Berry and Young 2001), thus reducing the transport of sediment to the Mississippi River and, eventually, the Gulf of Mexico (NRC 2011). These modifications included the construction of the six dams (Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point) that make up the mainstem reservoir system and smaller dams along tributaries between 1932 and 1957 as well as the Missouri River Bank Stabilization and Navigation Project.

Blevins (2006) reported that the median suspended sediment concentration at Hermann, Missouri was 378 mg/L during 1973-2002, which was less than 25 percent of the concentration in 1907 and less than 20 percent in 1929-1932, as recorded near St. Charles, Missouri. Blevins (2006) attributed decreased turbidity in the lower Missouri River largely to settling of suspended particles in the upriver reservoirs and reduced channel bed and bank erosion, resulting from bank stabilization activities during the 1950s.

Decreased turbidity and sediment loading likely have affected native fish species that are morphologically and behaviorally adapted to high turbidity, such as pallid sturgeon, paddlefish (*Polyodon spathula*), blue sucker (*Cycleptus elongates*), and flathead chub (*Platygobio gracilis*) (Pflieger and Grace 1987). Galat et al. (2005b) have reported that 11 of the 73 “big river” fish species in the Missouri River mainstem are now imperiled due to combined factors such as impoundments, changes in flow and temperature regimes, reductions in channel habitat diversity, reduced turbidity, and species introductions. Reductions in these species have corresponded to increases in sight-feeding species and non-native sport fishing species that are more tolerant of the altered temperature, turbidity, and habitat (NRC 2002).

Turbidity tends to increase with downstream distance in the LMOR with suspended sediment concentrations ranging from 7.3 metric tons per year (Mt/year) at Sioux City, IA to 58 Mt/year at Hermann, MO. Gavins Point Dam, which impounds Lewis and Clark Lake at RM 811, is the most downstream of the mainstem dams, and water released from it has very low turbidity with a median of 10 NTU (USACE 2016c). Discharges from the James and Vermillion Rivers add to the turbidity, however major sediment inputs come from tributaries located farther downstream (Poulton et al. 2005). In general, the relative sediment inputs contributed by these tributaries to the lower mainstem reaches are much larger than inputs from upper mainstem tributaries (NRC 2011). Table 2-1 shows that turbidity generally increases with distance along the lower river (USACE 2016c).

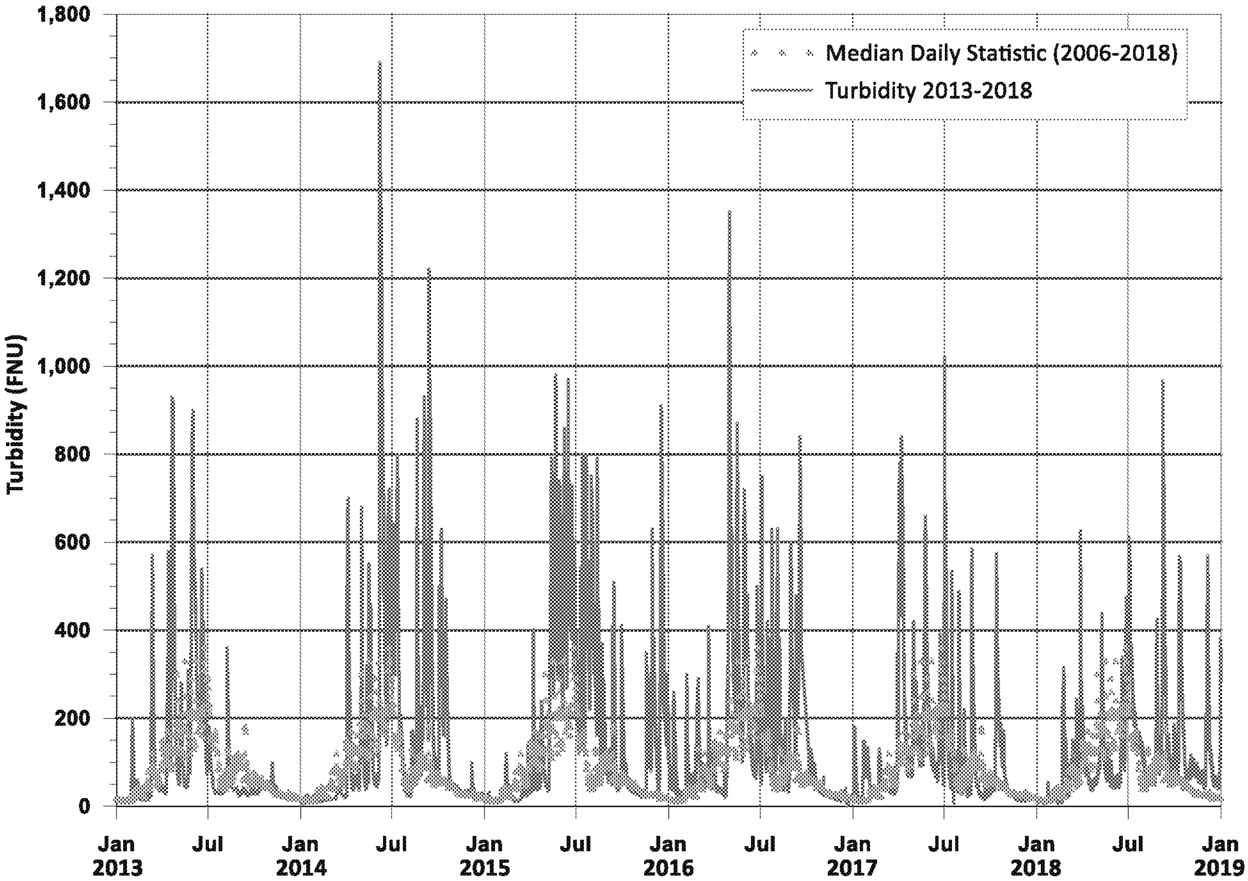
Table 2-1 Turbidity in the Lower Missouri River (2012–2014).

	Median Turbidity (NTU)		
Location[1]	2012	2013	2014
Ponca, NE	—	25.0	22.3
Decatur, NE	—	35.9	32.0
Omaha, NE	—	61.7	39.9
Nebraska City, NE	—	61.7	42.2
Rulo, NE	—	63.0	12.7
Atchison, KS	46.2	68.6	105.0
Kansas City, MO	49.6	90.1	99.5
Waverly, MO	70.4	135.4	87.3
Glasgow, MO	107.6	111.6	264.9
Marion, MO	112.8	99.5	164.2
Hermann, MO	97.3	67.7	135.6

Weldon, MO	96.1	69.8	133.4

Source: USACE 2016c.
[1] Gage station locations are ordered from upstream to downstream.

Figure 2-16 presents turbidity measurements in Formazin Nephelometric Units (FNU) measured at the Hermann gage from 2013 through 2018. Seasonal trends indicate that turbidity increases throughout spring into early summer within minimum values occurring during winter.



Source: USGS 2019.

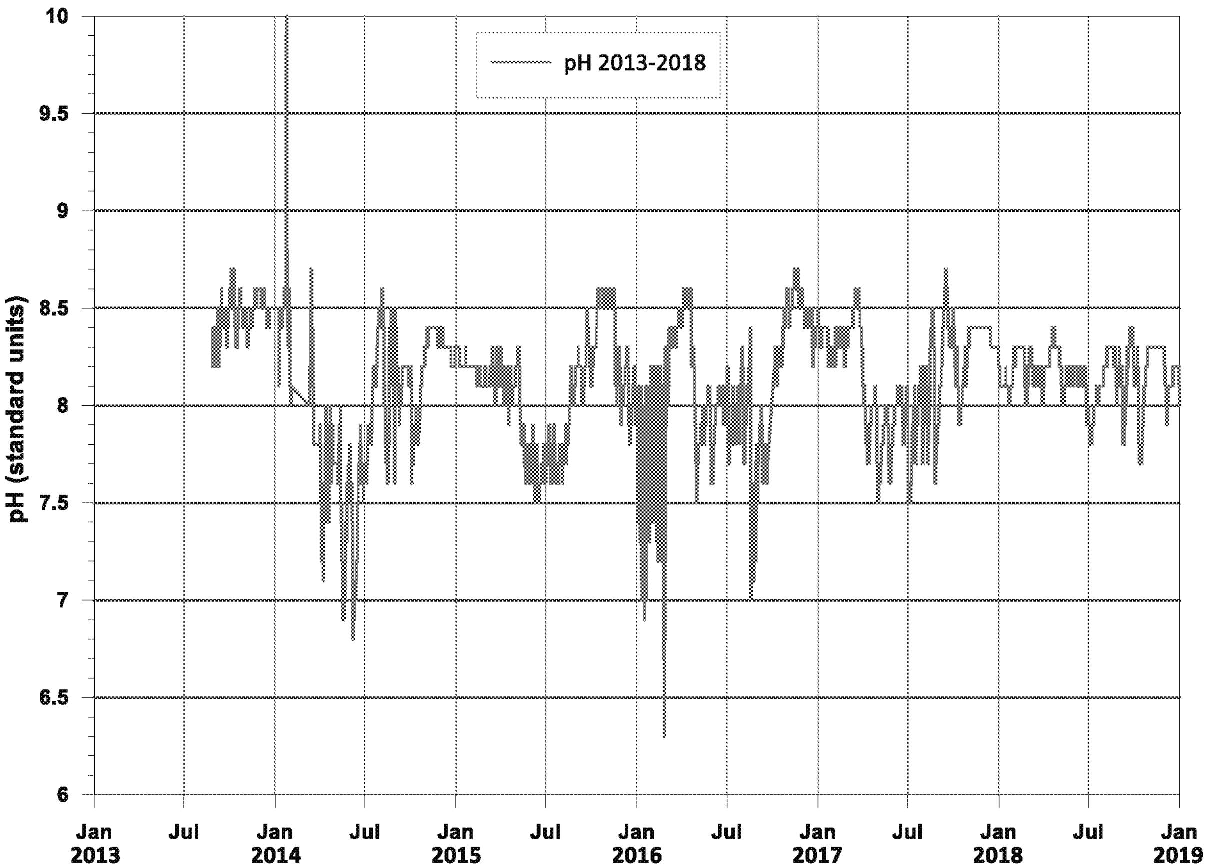
Figure 2-16 Turbidity Levels (FNU) at Hermann Gage, MO.

Table 2 A-4 (Appendix 2 A) shows the monthly mean discharge of suspended sediment in short tons per/day (STPD) measured at the Hermann gage from September 1948 through August 2016, which ranged from a low of 66,400 STPD for the December period of record to 723,000 STPD for June period of record, with peak discharges occurring in the April through June periods of record. The highest recorded sediment discharge at Hermann was 3,062,000 STPD in June 1951. Construction of the Gavins Point Dam began in 1952 and the facility began generating electricity in September 1956 (USACE 2018). Sediment discharge levels measured at Hermann greater than 2,000,000 STPD ceased after 1953. Sediment discharge levels between 1,000,000 and 2,000,000 STPD have been recorded infrequently, only during 1964, 1965, 1967, and 1973.

2.5.4 ph and Specific Conductance

The USGS routinely measures pH and specific conductance at the Hermann gage. These parameters are common water quality assessment metrics and are important for the health of ecological communities and human uses of the river. pH is a measure of how acidic or basic (alkaline) a solution is. The pH of natural waters is usually between 6.5 and 8.5, although wide variation can occur. Influences on pH levels include basin geology, industrial pollution and runoff, among other factors.

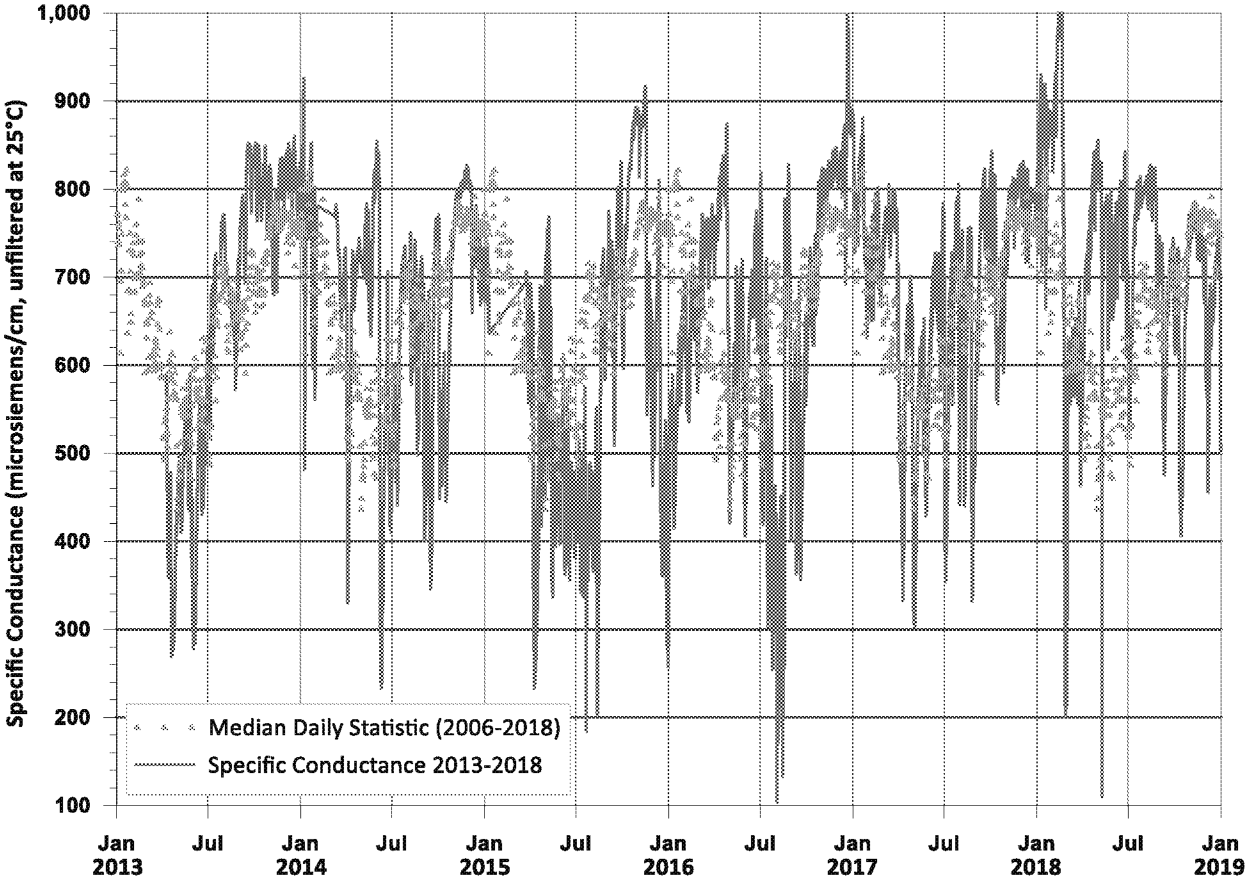
Measurements of pH at the Hermann gage made from mid-2013 through 2018 indicated that ambient conditions in the river are within a normal range and indicate a strong buffering capacity (Figure 2-17).



Source: USGS 2019.

Figure 2-17 pH Levels at Hermann Gage, MO.

Figure 2-18 shows the specific conductance (microsiemens/cm, unfiltered at 25°C) of ambient river water at Hermann for the period of April 2013 to December 2018. Specific conductance is most often a function of the total dissolved solids suspended in the water column. Thus, primary influences on this metric include rainfall, runoff, and snowmelt. Specific conductance at Hermann exhibits a seasonal pattern that correlates with runoff and rainfall throughout the year. Common minerals comprising the soils and geology of the watershed often comprise most dissolved solids in surface waters, such as calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride ions. As concentrations of dissolved ions increase, specific conductance of the water increases. Temperature also strongly affects the electrical conductivity of water; therefore, specific conductance is normalized to represent values expected at a temperature standard of 25 °C (USGS 2010).



Source: USGS 2019.

Figure 2-18 Specific Conductance (µS/cm) at Hermann Gage, MO.

2.5.5 Nutrients

Higher flow discharges from Gavins Point Dam are associated with higher nutrients in the dam discharge (USACE 2016a). Nitrogen and phosphorus concentrations are reported to be much greater along the lower river due to point and nonpoint source nutrient inputs from urban areas and agriculture. Nutrient concentrations are variable along the reach below the dam, but they tend to increase downstream (USACE 2016a). Nitrate-nitrogen amounts are much greater than those observed in the inter-reservoir and reservoir reaches (Blevins and Fairchild 2001; Havel et al. 2009). An increase in nitrate-nitrogen concentrations with distance downstream from Gavins Point Dam is caused by inflows from several highly agricultural watersheds between Yankton, SD and St. Joseph, Missouri (Blevins et al. 2014). The urban areas of Sioux City and Omaha also contribute to the high loads (USACE 2016c). Below Sioux City, tributaries entering the Missouri River add nitrogen and phosphorous, nearly doubling the amount of these nutrients, especially close to Omaha (Blevins and Fairchild 2001; Havel et al. 2009).

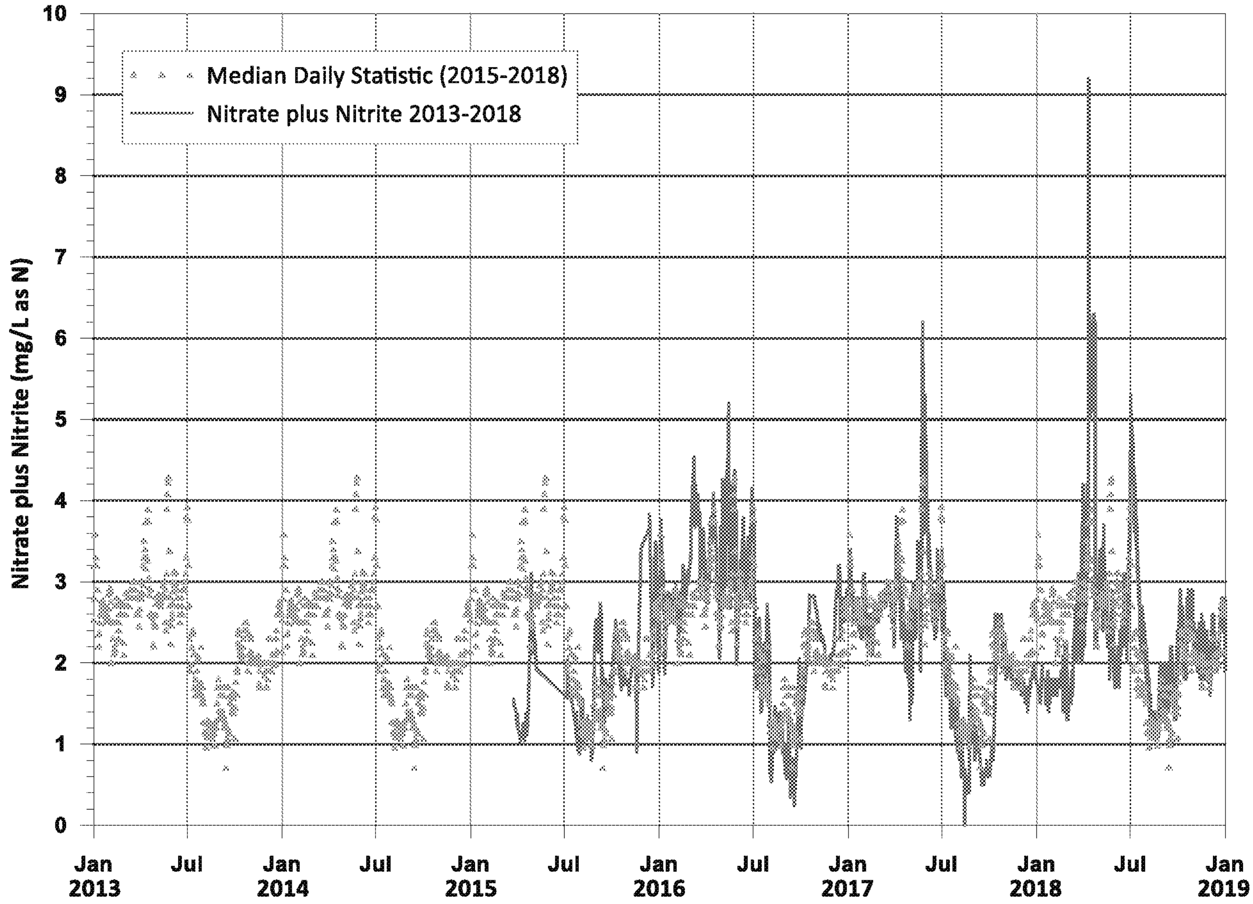
Table 2-2 presents nutrient concentrations measured in 2012 through 2014 at sites along the lower reaches of the Missouri River from Ponca, NE to Weldon, MO.

Table 2-2 Nutrient Concentrations in the Lower Missouri River (2012–2014).

Location[1]	Median Nitrate-Nitrite Nitrogen (mg/L)			Median Total Phosphorus (mg/L)		
	2012	2013	2014	2012	2013	2014
Ponca, NE	—	0.07	0.06	—	0.05	0.05
Decatur, NE	—	0.55	0.20	—	0.11	0.10
Omaha, NE	—	0.78	0.51	—	0.18	0.11
Nebraska City, NE	—	0.85	0.82	—	0.24	0.23
Rulo, NE	—	0.96	0.22	—	0.24	1.38
Atchison, KS	1.01	1.10	1.50	0.23	0.20	0.60
Kansas City, MO	0.87	1.40	1.50	0.32	0.23	0.51
Waverly, MO	0.94	1.40	1.40	0.29	0.31	0.49
Glasgow, MO	1.00	1.40	1.02	0.32	0.32	0.83
Marion, MO	0.80	1.55	1.00	0.29	0.29	0.69
Hermann, MO	0.74	1.30	1.00	0.28	0.24	0.56
Weldon, MO	0.84	0.71	1.02	0.26	0.25	0.72

Source: (USACE 2016c)
[1] Gage station locations are ordered from upstream to downstream.

Figure 2-19 shows the concentration (mg/L) of nitrate (NO3) plus nitrite (NO2) measured at the Hermann gage for the period from 2013 through December 2018. The range was <1.0 mg/L to >5.0 mg/L. Nitrogen levels showed a seasonal pattern with higher concentrations coinciding with periods of higher river flows. Table 2 A-2 (Appendix 2 A) presents monthly mean nitrogen data at Hermann for the period of 2015 through 2018. Monthly mean nitrogen levels measured during this period ranged from 0.787 mg/L to 4.185 mg/L. Excess nitrogen can cause excessive growth of aquatic macrophytes and algae. Excessive growth of aquatic plants, particularly floating and suspended phytoplankton, can clog water intakes, depress DO levels during decomposition, and impede light penetration into deeper waters.



Source: USGS 2019.

Figure 2-19 Nitrate plus Nitrite (mg/L as N) Hermann Gage, MO.

2.5.6 Ecosystem Health

Compared to upper portions of the Missouri River, there are more urban areas and communities downstream of Gavins Point Dam that have a greater influence on Missouri River water quality through stormwater discharge and runoff and wastewater treatment plant discharge. The lower reaches of the Missouri River are especially influenced by urban and industrial sources from metropolitan areas such as Sioux City, Omaha, St. Joseph, and Kansas City (USACE 2016c). Arsenic concentrations as high as 4 µg/L have been detected in samples collected below the Gavins Point Dam, and concentrations of *Escherichia coli (E. coli)* bacteria exceeding state criteria have been found in Nebraska (NE) and Missouri sections of the river (MDNR 2016; NEDEQ 2016).

Contaminants known to bioaccumulate, such as chlordane and polychlorinated biphenyls (PCBs), have been found in some river sediments (MDNR 2016; NEDEQ 2016), and instances of lethal and chronic toxicity due to sediment contamination have been reported (Haring et al. 2010; Poulton et al. 2005). Sites immediately downstream of Kansas City have high levels of pesticides, PCBs, polycyclic aromatic hydrocarbons, metals, and polybrominated diphenyl ethers, but concentrations of these contaminants decrease farther downstream (Echols et al. 2008; Poulton et al. 2005). The pesticides acetochlor, atrazine, and prometon were present in samples collected at Decatur, NE, but not at levels that exceeded water quality criteria (USACE 2016a). The pesticides acetochlor, atrazine, bromacil, chlorpyrifos, ethalfluralin, and metolachlor were present in samples collected at Omaha, although only chlorpyrifos was present at levels that exceeded water quality criteria (USACE 2016a). At Nebraska City and Rulo, NE, the pesticides acetochlor, atrazine, and metolachlor were present, but not at levels that exceeded water quality criteria (USACE 2016a). Missouri River tributaries in the lower river contribute E. *coli*, selenium, atrazine, dieldrin, PCBs, mercury, nutrients, chlordane, and sediments, potentially influencing water quality (USACE 2016a).

Organochlorine pesticides, particularly chlordane, heptachlor, and dieldrin along with polyaromatic hydrocarbon compounds (PAH) in the lower river were detected by sampling the water column at Hermann, MO (Petty et al. 1993). The Missouri Department of Health and Senior Services has issued a fish consumption advisory against consumption of shovelnose sturgeon (*Scaphirhynchus platorynchus*) eggs from the Missouri River due to PCB and chlordane contamination, and a consumption limit of one meal per month for shovelnose sturgeon flesh due to PCB, chlordane, methyl mercury contamination. There also is a consumption limit of one meal per week for flathead catfish (*Pylodictis olivaris*), channel catfish (*Ictalurus punctatus*), and blue catfish (*I. furcatus*) greater than 17 in. in length and common carp (*Cyprinus carpio*) greater than 21 in. from the Missouri River (MDHSS 2017).

Angradi et al. (2011) evaluated the health of the Missouri River ecosystem in comparison to the Upper Mississippi River and Ohio River, as part of the USEPA's Environmental Monitoring and Assessment Program for Great River Ecosystems (EMAP-GRE). Ecosystem health or condition was categorized as either most-disturbed condition, intermediate condition, or least-disturbed condition and quantified in terms of percentage of river length by condition category. Condition was assessed based on observed biological response indicators, including fish and macroinvertebrates, trophic state (chlorophyll a concentration), macrophyte cover (submerged aquatic vegetation or SAV), and exposure of fish-eating predators to toxic contaminants (e.g., mercury, chlordane, DDT, and PCBs) in fish tissue. They also estimated the extent of stressors, including nutrients, total suspended solids, sediment toxicity, invasive species, and land use.

Approximately 17 and 29 percent of the Missouri River was in most-disturbed condition for total nitrogen and total phosphorus, respectively, with phosphorus concentrations increasing progressively downriver from the Gavins Point Dam. Greater than 12 percent of the river length was found to have sediments resulting in toxicity to exposed organisms (Angradi et al. 2011). In comparison to the Mississippi and Ohio Rivers, the Missouri River was less stressed by invasive species, which included *Dreissena* species (zebra and quagga mussels), and two Asian carps, bighead carp (*Hypopthalmichthys nobilis*) and silver carp (*H. molitrix*). Approximately 24 and 13 percent of the Missouri River was in least-disturbed condition according to assemblages of benthic macroinvertebrates and fish, respectively. Except for mercury, concentrations of fish tissue contaminants known to be toxic to wildlife increased downstream of the mainstem. Based on chlorophyll concentrations, eutrophic conditions also tended to increase progressively downriver from the Gavins Point Dam with 24 percent of the overall river considered eutrophic largely because of agricultural land use on the floodplain (Angradi et al. 2011).

As stated previously, general causes of water quality degradation in the LMOR include sediment, nutrient, and pesticide runoff from agriculture; sediment and metal loadings from mines; urban stormwater discharges; wastewater and industrial plant discharges; septic system leaching; and entrapment of sediments and pollutants behind dams.

From its mouth at St. Louis to the Gasconade River, the river has designated use support for a warm-water fishery, drinking water, recreation, agriculture, industrial, and livestock and wildlife watering (USACE 2006). This lowermost section of the river (St. Charles/St. Lewis Counties) in proximity to LEC is included in Missouri's § 303(d) 2016 list of impaired waterbodies due to bacteria (E. coli), with impaired use for whole body contact recreation (MDNR 2016). This impaired segment was first added to the § 303(d) registry in 2008 and it includes waters that are part of a public water supply. In the channelized reach, there is also a gradual downstream degradation due to point and nonpoint sources and tributary inflows, particularly in terms of nutrient concentrations (e.g., organic nitrogen, nitrate, total phosphorus, and ortho-phosphorus).

2.5.7 Future Climate

USACE (2016b) assessed how climate change could potentially affect actions under the MRRP. With climate change, USACE (2016b) noted that the Missouri River basin will likely experience increased temperatures and precipitation. Increased precipitation will result in higher streamflow, while increased temperatures will likely result in earlier spring snowmelt, decreased snowmelt season duration, and decreased peak snowmelt flows. Increased air temperatures could also have impacts on water temperatures and water quality. Rainfall events will likely become even more sporadic for the entire Missouri River basin. Large rain events will likely become more frequent and interspersed by longer, relatively dry periods. Extremes in climate will likely also magnify periods of wet or dry weather, resulting in longer, more severe droughts, and larger more extensive flooding.

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3. 40 CFR 122.21(r)(3) – COOLING WATER INTAKE STRUCTURE DATA

This section presents the available data on the operations of the CWIS at the LEC.

3.1 COOLING WATER INTAKE STRUCTURE OPERATION AND FLOWS

The current cooling water process employed at the LEC is once-through cooling. This system withdraws water from the Missouri River, circulates it through pipes to absorb heat from the steam within condensers, and then discharges the warmer water through a discharge channel back to the river. At a normal water level of El. 455 ft, the DIF of the LEC is currently 1,005,378 gpm (1,448 MGD, 2,240 cfs). This flow includes all eight circulating water pumps running at 125,672 gpm each.

In May and June of 2017, the daily average intake flow for the LEC was as low as 1,698 cfs and as high as 2,346 cfs. While these flows do not bound the possible flow extremes, they demonstrate the variability of intake flow which is influenced by many environmental and operational factors, including the number of circulating water pumps in service, the condenser valving configuration, river elevation, and the cleanliness of the circulating water system. Pumps occasionally are removed from service for scheduled and unscheduled maintenance or other operational situations like unit outages, which reduces the intake flow at the facility. In addition, the facility can increase or decrease intake flows by opening or partially closing valves in the circulating water system. The river elevation also has an influence on intake flow with higher water levels corresponding to higher intake flows assuming all other parameters are held constant. Finally, the cleanliness of the circulating water system will play a role in intake flow. As the circulating water system (trash racks, traveling screens, condenser tube sheets, and condenser tubes) get dirty, the intake flow will be reduced.

The average daily intake flow, average annual AIF, and the DIF for the last 5 years (2014-2018) are provided in Table 3-1. Over this period, the LEC used approximately 84 to 94 percent of its full DIF annually. The average monthly withdrawal rate, number of days per month, and total monthly withdrawal for the past 5 years (2014-2018) are provided in Table 3-2.

Table 3-1 Estimated Actual Annual Intake Flow at LEC (2014-2018).

	2014[1]	2015[2]	2016	2017	2018
Estimated Actual Annual Intake Flows (Millions of Gallons)	445,926	498,450	449,965	457,533	457,967
Days per Year	365	365	366	365	365
Actual Intake Flow (MGD)	1,222	1,366	1,229	1,254	1,255
Estimated Design Intake Flow (Millions of Gallons)	528,520	528,520	529,968	528,520	528,520
Design Intake Flow (MGD)	1,448	1,448	1,448	1,448	1,448
Percent of Maximum Design Intake Flow	84%	94%	85%	87%	87%

Source: Ameren-Missouri Labadie Energy Center, 2019.
1 – Flow data were not available for September 18 to October 01, 2014.
2 – Flow data were not available for April 7-8, 2015.

Table 3-2 Estimated Monthly Actual Intake Flow at the LEC (2014-2018).

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2014[1]												
Average Daily Intake Flow (MGD)	1,235	1,217	1,255	1,017	971	1,427	1,475	1,401	1,115	1,124	1,137	1,280
Days Per Month	31	28	31	30	31	30	31	31	30	31	30	31
Monthly Intake Flow (millions of Gallons)	38,895	35,166	41,377	32,788	39,062	47,419	48,592	44,299	42,786	44,058	42,015	41,992
2015[2]												
Average Daily Intake Flow (MGD)	1,255	1,256	1,335	1,093	1,260	1,581	1,567	1,429	1,426	1,421	1,400	1,355
Days Per Month	31	28	31	30	31	30	31	31	30	31	30	31
Monthly Intake Flow (millions of Gallons)	38,895	35,166	41,377	32,788	39,062	47,419	48,592	44,299	42,786	44,058	42,015	41,992
2016												
Average Daily Intake Flow (MGD)	1,293	1,213	1,043	1,044	996	1,360	1,411	1,443	1,327	1,293	1,273	1,058
Days Per Month	31	29	31	30	31	30	31	31	30	31	30	31
Monthly Intake Flow	40,092	35,170	32,345	31,314	30,868	40,800	43,750	44,732	39,801	40,083	38,200	32,810

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
(millions of Gallons)												
2017												
Average Daily Intake Flow (MGD)	1,132	1,116	952	1,135	1,441	1,353	1,424	1,342	1,284	1,382	1,270	1,198
Days Per Month	31	28	31	30	31	30	31	31	30	31	30	31
Monthly Intake Flow (millions of Gallons)	35,093	31,244	29,521	34,060	44,674	40,594	44,143	41,595	38,535	42,835	38,114	37,126
2018												
Average Daily Intake Flow (MGD)	1,257	1,187	1,206	1,321	1,354	1,423	1,470	1,424	1,109	1,121	1,081	1,095
Days Per Month	31	28	31	30	31	30	31	31	30	31	30	31
Monthly Intake Flow (millions of Gallons)	38,959	33,229	37,378	39,628	41,974	42,688	45,558	44,153	33,269	34,755	32,417	33,960

Source: Ameren-Missouri Labadie Energy Center, 2019.
1 – Flow data were not available for September 18 to October 01, 2014.
2 – Flow data were not available for April 7-8, 2015.

3.2 COOLING WATER INTAKE STRUCTURE HYDRAULIC CONDITIONS

The LEC withdraws water from the channelized section of the LMOR, which extends approximately 735 miles from upstream of the facility near Sioux City, Iowa to the confluence with the Mississippi River north of St. Louis, Missouri. The normal water level of the river near the LEC is El. 455 ft.

Water levels recorded at the station (USGS 2017) were examined from April 2015 through 2017. During this period, the water level at the LEC ranged from a high of El. 478.8 feet to a low of 449.3 feet. The average daily water level during this period was El. 457.2 feet.

Velocities within the CWIS for LEC have been calculated at the design low water level (DLWL) (El. 450.0 feet) and mean water level (MWL) (El. 455.0 feet). The calculated approach and through-screen velocities at each water level are shown in Table 3-3.

Table 3-3 Calculated Velocities within the LEC CWIS.

LEC CWIS Condition	DLWL	MWL
Traveling Water Screen Approach Velocity (fps)	1.34	1.13
Traveling Water Screen Through-Screen Velocity (fps)	1.96	1.67

3.3 WATER BALANCE

A water balance diagram for the LEC is provided in Figure 3-1. In addition, a PDF version of the diagram has been provided to MDNR as part of the § 316(b) compliance and NPDES application package.

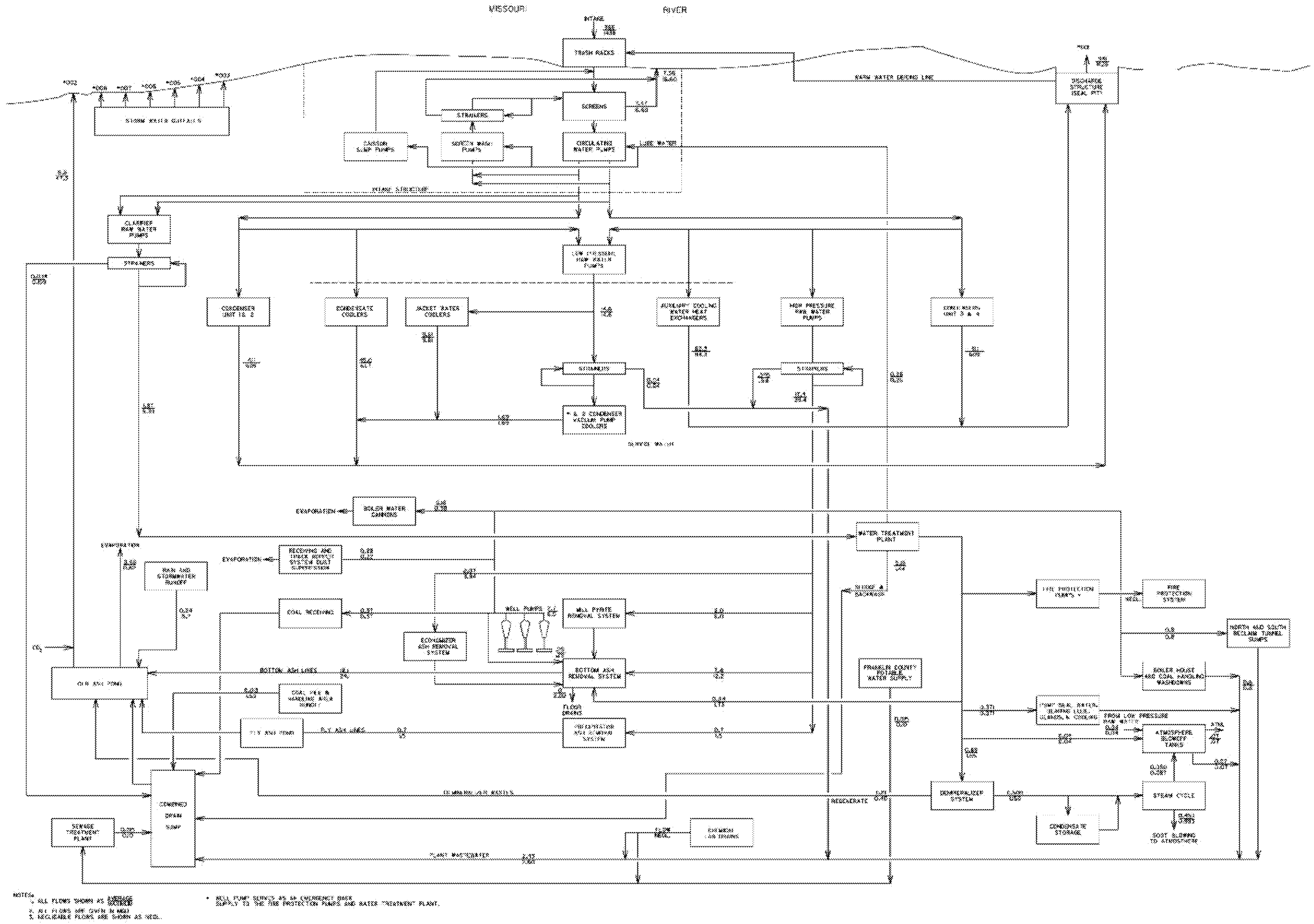


Figure 3-1 The LEC Water Balance Diagram.

3.4 REFERENCES

USGS. 2017. National Water Information System: Web Interface, USGS Surface Water Data, Missouri River Gage at Labadie, MO. Available on-line at: https://www2.usgs.gov/water/. Site last accessed 2 March 2018.

4. 40 CFR 122.21(r)(4) – SOURCE WATER BASELINE BIOLOGICAL CHARACTERIZATION DATA

This section presents the available data to characterize the biological community in the vicinity of the CWIS of the LEC.

4.1 PROTECTIVE MEASURES AND STABILIZATION ACTIVITIES

The LEC has not implemented any protective measures or stabilization activities that could affect the baseline water condition near the intake.

4.2 INFORMATION AND SOURCING EFFORTS

Sufficient information was available on the aquatic community of the Missouri River within the vicinity of the LEC CWIS to address the data requirements in paragraphs (r)(4)(ii) through (r)(4)(vi) under § 122.21(r)(4) of the § 316(b) Rule. Two multi-year survey programs (Berry and Young 2001; Berry et al. 2004; Herman et al. 2014; Herman and Wrasse 2015, 2016), one of which is ongoing, routinely sampled fish communities within segments of the LMOR to assess the abundance, distribution, habitat usage, and population structure of target fish species, such as the endangered pallid sturgeon (*Scaphirhynchus albus*), as well as the overall fish community present in the river. Academic studies relevant to the composition, distribution, and behavior of fish communities in the LMOR are cited throughout this report.

Multiple fish population surveys dating back to 1974 have been conducted in the immediate vicinity of the LEC (Ameren 2002), including a recent biological monitoring program initiated in February 2017 that continued through January 2019 (ASA 2019). Impingement monitoring at the LEC CWIS was previously conducted during 1974-1975 (EEHI 1976a) and 2005-2006 (ASA and Alden 2008). An entrainment characterization study was conducted at the LEC in 2015 and 2016. Findings from freshwater mussel surveys conducted in the river near the LEC (ASA 2019) and along the LMOR (Perkins and Backlund 2000, Hoke 2009) as well as records of species known to be present in Franklin County, Missouri (INHS 2018) were used to determine which species potentially occur near the LEC. Data from the recent biological monitoring program along with results from the aforementioned studies were summarized within this report to meet the following specific (r)(4) requirements:

> *(ii)—requires a list of species (or relevant taxa) for all life stages and their relative abundance near the CWIS.*
>
> *(iii)—requires the identification of species and life stage that would be most susceptible to impingement and entrainment. Species evaluated must include the forage base as well as those important in terms of significance to commercial and recreational fisheries.*
>
> *(iv)—requires identification and evaluation of the primary period of reproduction, larval recruitment, and period of peak abundance of relevant taxa.*
>
> *(v)—requires data representative of the seasonal and daily activities (e.g., feeding and water column migration) of biological organisms near the cooling water intake structure.*

Those listed T&E species potentially present in the vicinity of the LEC were identified through literature searches and review of the findings of relevant sampling programs conducted in relative proximity to the facility.

(vi)—*requires the identification of* *all Federally-listed* *threatened and endangered species and/or designated critical habitat that are or may be present in the action area.*

4.3 FEDERALLY LISTED THREATENED AND ENDANGERED SPECIES

In accordance with § 122.21(r)(4), subpart (vi) of the Rule, the owner/operator of the facility must identify all federally-listed threatened and endangered species and/or designated critical habitat that are or may be present in the action area affected by the CWIS. The § 316(b) Rule does not require that new studies be conducted if data on federally-listed species are absent or even limited for completing the (r)(4) report.

4.3.1 Aquatic Threatened and Endangered Species and critical habitat

The pallid sturgeon is the only aquatic federally-listed threatened and endangered species within the Missouri River near the LEC CWIS. There is also no critical habitat located in the Missouri River near the LEC CWIS.

4.3.2 State and Federal Consultations

There have been no formal State and/or Federal consultations regarding the pallid sturgeon. An informal consultation was held with the USFWS regarding the possible collection of a larval pallid sturgeon. However, a definitive identification could not be made.

4.3.3 Public Participation

There has been no need for public participation regarding the pallid sturgeon since there have been no formal State or Federal consultations.

4.4 FISH COMMUNITY COMPOSITION

This section identifies fish species present in the LMOR and in the vicinity of the LEC and describes changes in the fish community occurring over the last four decades. First, methodologies and a summary of results from past and recent fishery surveys are discussed, followed by a summary of data collected from impingement and entrainment studies conducted at the LEC CWIS, information on spatial and temporal variation of fish species, and a description of the species composition and structure of the fish community.

4.4.1 LMOR Fish Survey Programs

The LEC under Ameren (and formerly Union Electric Company) has conducted numerous biomonitoring programs with the objective of characterizing the aquatic communities present in the immediate vicinity of the facility to distinguish possible impacts related to plant operation from natural variation in populations. Past programs included surveys of fish populations performed primarily using electrofishing. The original program was conducted during 1974-1975 as part of § 316(a) and § 316(b) studies (EEHI 1976b). Follow-up studies took place during 1980-1985 and 1996-2001 (Ameren 2002), and a two-year biological monitoring program was conducted from February 2017 through January 2019 (herein referred to as 2017-2018 biological monitoring program) that included electrofishing as well as additional sampling gears (ASA 2019).

The PSPAP is an ongoing, collaborative monitoring program within the Missouri River overseen by the USACE that was initiated in 2003 under the MRRP and includes members representing state and federal agencies as well as university researchers (MRRP 2013). The goals of the program are to evaluate annual and long-term trends of abundance, distribution, habitat usage, and population structure of the federally-endangered pallid sturgeon (wild and stocked). Native target species also were collected, including the shovelnose sturgeon (*Scaphirhynchus platorynchus*), blue sucker (*Cycleptus elongatus*), sauger (*Sander canadensis*), plains minnow (*Hybognathus placitus*), western silvery minnow (*Hybognathus argyritis*), sand shiner (*Notropis stramineus*), sturgeon chub (*Macrhybopsis gelida*), sicklefin chub (*Macrhybopsis meeki*), and speckled chub[1] (*Macrhybopsis aestivalis*), and non-target species also were collected. Annual surveys using multiple sampling gears are conducted within 14 river segments that extend from the Fork Peck Dam in Montana to the confluence with the Mississippi River near St. Louis, Missouri. Results from recent sampling conducted during 2013-2015 in the segment (14) where the LEC is located (Herman et al. 2014, Herman and Wrasse 2015, 2016) are summarized herein.

The BFS was a multiyear, largescale survey of fish populations within the Missouri River conducted by a group of state and federal agencies and research organizations with the goal of evaluating changes in the fish community to assist the USACE in managing the Missouri River system (Berry and Young 2001, Berry et al. 2004). Multiple sampling gears were used during annual surveys conducted during 1996-1998 in 15 river segments that extended from the river's headwaters in Montana at RM 1,999 to the confluence with the Mississippi River near St. Louis, Missouri. Twenty-six species were targeted for evaluation based on their primary habitat use of benthic habitat, importance as prey or to commercial and recreational fishing, and wide distribution in the river. However, non-target species collected during sampling were recorded as well. Catches from the two segments (25 and 27) surveyed as part of the BFS located in closest proximity to the LEC are summarized herein.

4.4.2 LEC Biomonitoring: Methodology and Results

Electrofishing during 1974-1975 was conducted monthly (excluding January-March) over one year at three sites that were located upstream of the intake structure, within the discharge canal, and downstream of the canal (Sites 1-3 in Figure 4-1 approximate these locations). A fourth site (Site 4 in Figure 4-1) was used during 1980-1985, when sampling was conducted quarterly to represent the seasons as follows: spring (March-May), summer (June-August), fall (September-November), and winter (December-February). The same sampling frequency was used during 1996-2001, when a fifth site was surveyed (Site 5 in Figure 4-1). The sampling sites extended 1.8 mi from RM 58.3 to RM 56.5. Boat electrofishing was conducted using 230 volts with three-phase, alternating current (AC) during 1974-1975, whereas later efforts primarily employed 240 volts of single-phase AC with pulsed-direct current (DC) used in the fall of 2001. Fish were identified, counted, weighed, and measured for length prior to release (Ameren 2002).

Approximately 6.3 hours of electrofishing conducted during 1974-1975 yielded a total catch of 313 fish representing 21 species (Table 4-1). Electrofishing was conducted over 26.4 hours (19 samples) and 31.5 hours (20 samples) during the 1980-1985 and 1996-2001 monitoring periods, respectively. The 1980-1985 catch totaled 3,219 fish and 38 species and the 1996-2001 catch consisted of 3,706 fish belonging to 39 taxa (38 species, 1 hybrid). A total of 46 unique taxa (45 species, 1 hybrid) were collected across the three monitoring periods.

[1] The shoal chub (*Macrhybopsis hyostoma*) was elevated to full species status from the speckled chub species-complex through morphological studies by Eisenhour (1999, 2004) and genetic studies by Underwood et al. (2003). Henceforth, all specimens formerly identified as speckled chub are now identified as shoal chub.

Dominant taxa were fairly consistent across the survey periods as gizzard shad (*Dorosoma cepedianum*) accounted for more than 54 percent of the total combined catch (Table 4-1). Ten species collectively comprised another 39 percent of the total catch, which included common carp (*Cyprinus carpio*), freshwater drum (*Aplodinotus grunniens*), river carpsucker (*Carpiodes carpio*), goldeye (*Hiodon alosoides*), shortnose gar (*Lepisosteus platostomus*), channel catfish (*Ictalurus punctatus*), blue catfish (*Ictalurus furcatus*), flathead catfish (*Pylodictis olivaris*), smallmouth buffalo (*Ictiobus bubalus*), and white bass (*Morone chrysops*). A number of species known to be common in the section of the LMOR near the LEC were not sampled in abundance due to gear selectivity (sampling bias) of electrofishing. Among those species were shovelnose sturgeon, sauger, red shiner (*Cyprinella lutrensis*), paddlefish (*Polyodon spathula*), blue sucker, and grass carp (*Ctenopharyngodon idella*). Body conditions improved for nearly all species during 1996-2001 relative to 1980-1985 as indicated by increases in the maximum weight observed for each species (Table 4-2).

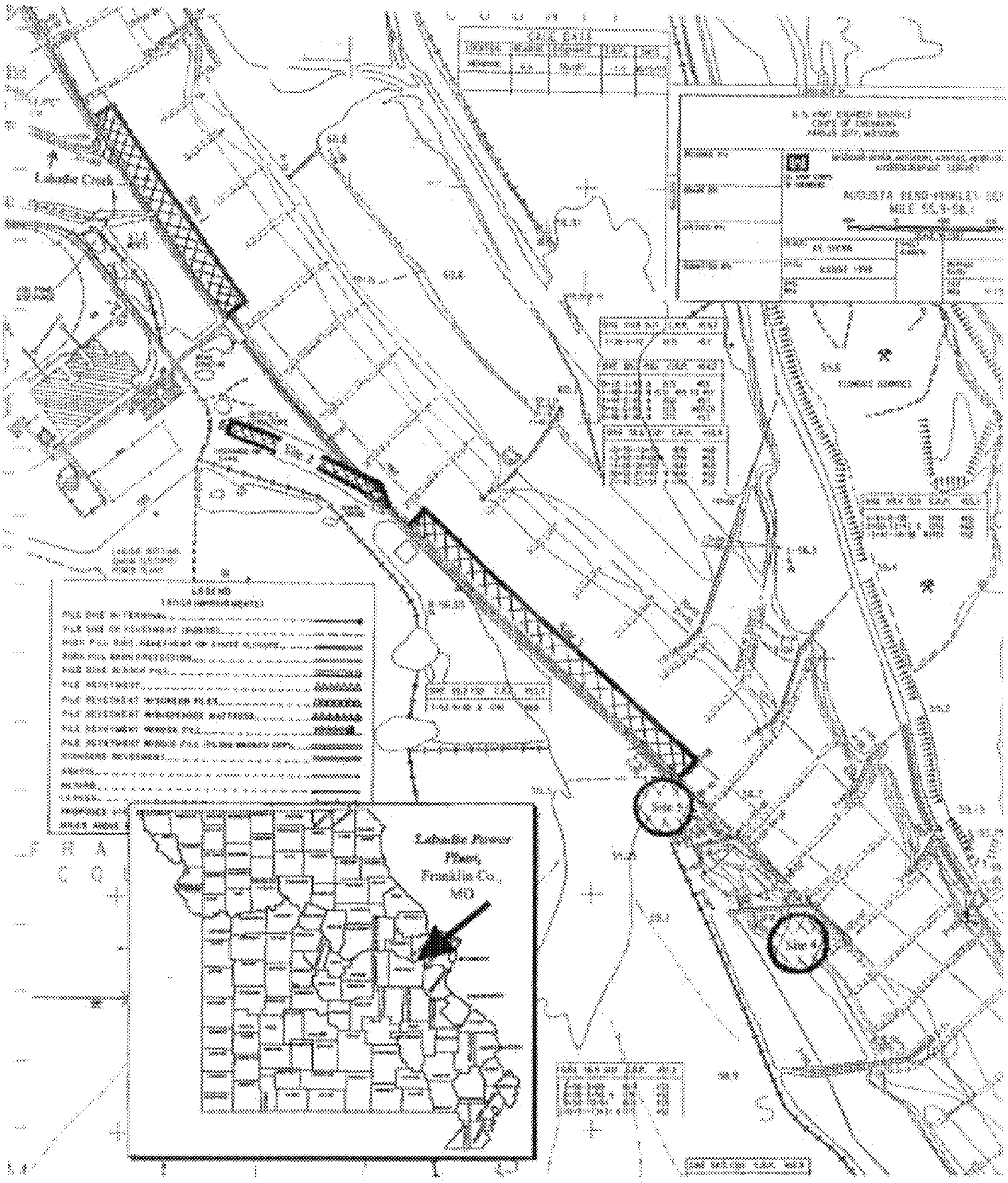
A two-year biological monitoring program was conducted at the LEC from February 2017 through January 2019 (ASA 2019). Fish surveys consisted of pulsed-DC electrofishing (240 volts), trawling, hoop netting, bag seining, and ichthyoplankton sampling to reduce gear bias and effectively sample all habitat types present in the surrounding area. Four sampling zones located along a 12-mile reach extending from RM 62 to RM 50 (Figure 4-2) corresponded to an upstream control zone (Zone 1), the discharge canal (Zone 2), a thermally-exposed zone (Zone 3), and a downstream zone (Zone 4). Monthly sampling was performed for all gears other than ichthyoplankton sampling and specific gears were used to target particular habitat types (main channel, channel border, and wing and L dike field) found in each zone. Electrofishing (channel border and wing and L dikes) consisted of 20-minute runs conducted during the day using 240 volts of pulsed-DC. Trawl samples (all habitat types) were collected over 3-5 minutes during the day using an 8-foot head rope mini-Missouri trawl. A 30-foot × 6-foot bag seine was used to make two seine hauls from dike field habitat during the day. Ichthyoplankton sampling (wing and L dikes) was conducted biweekly from mid-March through July and monthly during August and September by performing two 3.5-minute tows with a 1-meter conical plankton net such that the entire water column was sampled. All gears were used to sample habitats located in the river (Zones 1, 3, and 4), but sampling in the discharge canal (Zone 2) was limited to electrofishing. Collected fish were identified and counted in the field and up to 30 individuals per species were weighed and measured for length prior to release.

The results from the fish component of the two-year biological monitoring program (ASA 2019) are summarized herein. A total of 25,265 fish representing 70 species and two hybrids were collected in the vicinity of the LEC when combining catches made from 288 trawl, 240 electrofishing, 216 hoop net, and 96 seine samples (Table 4-3). Red shiner, channel shiner (*Notropis wickliffi*), gizzard shad, and emerald shiner (*Notropis atherinoides*) were the most abundant species, collectively accounting for approximately 56 percent of the total catch. Also numerous were shoal chub (*Macrhybopsis hyostoma*), sicklefin chub, freshwater drum, blue catfish, channel catfish, and bullhead minnow (*Pimephales vigilax*). Catches made using seining and trawling comprised approximately 46 and 30 percent of the total catch, respectively.

Ichthyoplankton sampling conducted as part of the 2017-2018 biological monitoring program indicated that composition is relatively similar among the three zones of the river sampled near the LEC (Table 4-4). Asian carps, including specimens identified as belonging to the genus *Hypophthalmichthys* such as silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Hypophthalmichthys nobilis*) as well as grass carp and eggs that could not be identified to a genus, represented over 96 percent of all specimens collected. Excluding Asian carp, other abundant taxa included freshwater drum, buffalos (subfamily Ictiobinae), and gizzard shad.

One fish was preliminarily identified as the federally-endangered pallid sturgeon during the recent monitoring program conducted near the LEC. However, its identity could not be definitively confirmed due to lack of DNA evidence required for genetic analysis. As a result, the identification of this specimen remained as an unidentified river sturgeon (*Scaphirhynchus* sp.) (Table 4-3). The shovelnose sturgeon, which is currently listed as a federally-threatened species due to its similarity in appearance to the federally-endangered pallid sturgeon (USFWS 2010), was collected during recent and past sampling at the LEC. Several lake sturgeon (*Acipenser fulvescens*), a Missouri state-endangered species, also were collected near the LEC during recent monitoring. No other federal or state-listed species were identified during the past or recent monitoring periods.

The Missouri Natural Heritage Program (MONHP) also maintains a ranking system (S1-S5) that indicates the level of concern for the continued existence of a species in the state (MDC 2018). Species assigned ranks of S1, S2, and S3 are considered "critically imperiled," "imperiled," and "vulnerable," respectively. Ranks S4 and S5 indicate species that are "apparently secure" and "secure," whereas an SU designation indicates that a species is "unrankable" due to a lack of information or the presence of conflicting information its status. Pallid sturgeon and lake sturgeon both have S1 rankings. Two species assigned an S2 ranking, ghost shiner (*Notropis buchanani*) and plains minnow, and one species assigned an S3 ranking, sturgeon chub, were collected during recent monitoring surveys conducted near the LEC. Two species with SU rankings, skipjack herring (*Alosa chrysochloris*) and American eel (*Anguilla rostrata*), were collected during current or past sampling.



Source: Ameren 2002.

All five sites were sampled during 1996-2001 monitoring, whereas Sites 1-3 approximately correspond to sampling during 1974-1975 and 1980-1985.

Figure 4-1 The LEC Biomonitoring Sampling Sites Located Between RM 58.3 and RM 56.5 of the LMOR.

Table 4-1 Number and Percent Composition of Fish Taxa Caught During Electrofishing Surveys Conducted in the Vicinity of the LEC During 1974-1975, 1980-1985, and 1996-2001.

Taxon	Period of Biomonitoring			Combined Catch	
	1974-1975	1980-1985	1996-2001	Total	Percent Abundance
Gizzard shad	143	1,863	1,919	3,925	54.2
Common carp	32	120	445	597	8.2
Freshwater drum	11	275	170	456	6.3
River carpsucker	4	191	249	444	6.1
Goldeye	17	160	101	278	3.8
Shortnose gar	16	121	114	251	3.5
Channel catfish	1	68	163	232	3.2
Blue catfish	2	54	123	179	2.5
Flathead catfish	5	73	83	161	2.2
Smallmouth buffalo		23	110	133	1.8
White bass	1	60	51	112	1.5
Longnose gar	2	40	36	78	1.1
Emerald shiner	66			66	0.9
Chestnut lamprey	4	47	8	59	0.8
Striped bass × white bass			24	24	0.3
Bigmouth buffalo		9	15	24	0.3
White crappie	1	18	1	20	0.3
Bluegill		10	6	16	0.2
Brook silverside			15	15	0.2
Blue sucker		2	11	13	0.2
Skipjack herring	1	6	4	11	0.2
Black crappie		10	1	11	0.2
Mooneye		9	1	10	0.1
Grass carp		1	8	9	0.1
Quillback		3	6	9	0.1
Black buffalo		4	5	9	0.1
Largemouth bass		5	4	9	0.1
Sauger		7	2	9	0.1
Shorthead redhorse	1	6	2	9	0.1

Taxon	Period of Biomonitoring			Combined Catch	
	1974-1975	1980-1985	1996-2001	Total	Percent Abundance
Bighead carp			8	8	0.1
American eel	1	7		8	0.1
Silver carp			7	7	0.1
Spotted bass		4	2	6	0.1
Golden redhorse		4	1	5	0.1
Walleye		5		5	0.1
White sucker		1	3	4	0.1
Red shiner	2		2	4	0.1
Green sunfish	1	2	1	4	0.1
Paddlefish		1	2	3	<0.1
Longear sunfish		2	1	3	<0.1
Shovelnose sturgeon		2	1	3	<0.1
Striped bass		2	1	3	<0.1
Smallmouth bass		3		3	<0.1
Rock bass		1		1	<0.1
Mimic shiner	1			1	<0.1
Sand shiner	1			1	<0.1
Total	**313**	**3,219**	**3,706**	**7,238**	**100.0**
No. of species	**21**	**38**	**38**	**45**	
No of hybrids	**0**	**0**	**1**	**1**	

Source: Ameren 2002.

Table 4-2 Maximum Body Weight (lbs) for Species Collected During 1980-1985 and 1996-2001 and Percent Change Relative to 1980-1985.

Taxon	1980-1985	1996-2001	Percent Difference
Blue catfish	12.25	61.75	404.1
Flathead catfish	15.88	44.06	177.6
Common carp	12.44	16.75	34.7
Channel catfish	9.56	14.75	54.2
Grass carp	6.94	14.25	105.4
Smallmouth buffalo	3.44	14.13	310.9
Freshwater drum	2.94	10.63	261.7
Blue sucker	4.63	10.50	127.0
Bigmouth buffalo	8.44	9.38	11.1
Longnose gar	3.63	8.81	143.1
Paddlefish	5.75	7.38	28.3
River carpsucker	4.88	5.19	6.4
White bass	1.44	2.56	78.3
Quillback	0.50	2.44	387.5
Shovelnose sturgeon	1.44	2.00	39.1
Goldeye	1.38	1.50	9.1
Skipjack herring	0.81	1.00	23.1
Largemouth bass	0.75	0.81	8.3
Bluegill	0.13	0.25	100.0
Chestnut lamprey	0.13	0.19	50.0
Green sunfish	0.06	0.13	100.0

Source: Ameren 2002.

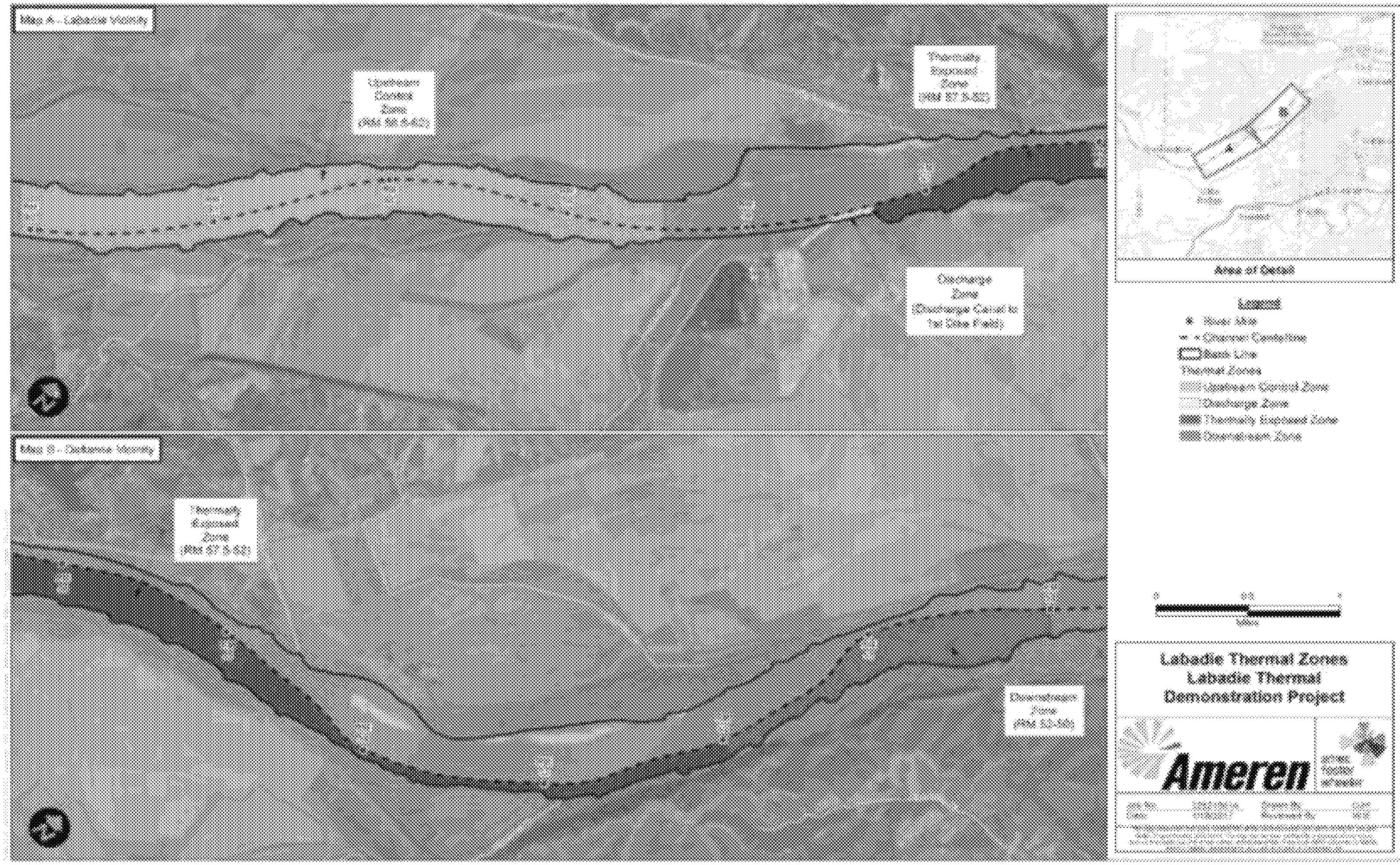


Figure 4-2 Four Zones Sampled During 2017-2018 Biological Monitoring Study Conducted at the LEC.

Table 4-3 Number of Fish Collected near the LEC by Sampling Gear During the 2017-2018 Biological Monitoring Study.

Taxon	Electrofishing	Hoop Net	Mini-MO Trawl	Seine	Total	Percent Abundance
Red shiner	1,224		58	5,219	6,501	25.7
Channel shiner	107		1,272	1,716	3,095	12.3
Gizzard shad	941	1	334	1,074	2,350	9.3
Emerald shiner	480		78	1,546	2,104	8.3
Shoal chub	7		1,361	434	1,802	7.1
Sicklefin chub			1,446	221	1,667	6.6
Freshwater drum	447	44	613	75	1,179	4.7
Blue catfish	372	44	638	2	1,056	4.2
Channel catfish	105	7	655	29	796	3.2
Bullhead minnow	42		198	410	650	2.6
Silver carp	244	12	212	20	488	1.9
Goldeye	147	18	155	37	357	1.4
Sand shiner	19		12	300	331	1.3
River carpsucker	285	26		7	318	1.3
Longnose gar	228	8	5	2	243	1
Shortnose gar	227		13		240	0.9
Smallmouth buffalo	160	42	1	24	227	0.9
Unidentified blacktail chubs (Macrhybopsis spp.)			128	52	180	0.7
Common carp	149	18	11	2	180	0.7
Flathead catfish	143	21	5	1	170	0.7
Shovelnose sturgeon	20	90	38		148	0.6
Western mosquitofish			2	138	140	0.6
Blue sucker	33	82	3		118	0.5
Orangespotted sunfish	17		50	43	110	0.4
Bluntnose minnow	6		4	91	101	0.4
Sturgeon chub			55	23	78	0.3
Bluegill	31		7	34	72	0.3
White bass	10	1	35	13	59	0.2
Grass carp	43	3	4	3	53	0.2
Spotted bass	33		2	4	39	0.2
Silver chub	1		23	10	34	0.1
Saugeye (Sauger x Walleye)	1	2	9	13	25	0.1
Black buffalo	22	1			23	0.1

Taxon	Electrofishing	Hoop Net	Mini-MO Trawl	Seine	Total	Percent Abundance
Unidentified sunfishes (Lepomis spp.)			16	7	23	0.1
Striped bass x white bass	17	3		2	22	0.1
Paddlefish		1	20		21	0.1
Unidentified carps and minnows (Cyprinidae family)			10	9	19	0.1
Bigmouth buffalo	16	2			18	0.1
River shiner	1		1	13	15	0.1
Green sunfish	11			2	13	0.1
Unidentified suckers (Ictiobinae subfamily)			13		13	0.1
Shorthead redhorse	7	5			12	<0.1
Buffalofish			5	6	11	<0.1
Golden redhorse	2		3	5	10	<0.1
Unidentified silver/bighead carp (Hypophthalmichthys spp.)			10		10	<0.1
Bighead carp	6	3			9	<0.1
Mooneye	6	1	2		9	<0.1
Unidentified crappies (Pomoxis spp.)			8		8	<0.1
Logperch	4		2	1	7	<0.1
Minnow Family group 2			6		6	<0.1
Unidentified mooneyes (Hiodon spp.)			6		6	<0.1
Plains minnow				6	6	<0.1
Rosyface shiner	1			5	6	<0.1
White crappie	6				6	<0.1
Brook silverside	2			3	5	<0.1
Unidentified carpsuckers (Carpiodes spp.)				5	5	<0.1
Skipjack herring	5				5	<0.1
Walleye	5				5	<0.1
Quillback carpsucker	4				4	<0.1
Sauger	3	1			4	<0.1
Unidentified shiners (Notropis spp.)			3	1	4	<0.1
Bigeye shiner				3	3	<0.1
Freckled madtom	3				3	<0.1
Ghost shiner			1	2	3	<0.1
Lake sturgeon	2	1			3	<0.1
Largemouth bass				3	3	<0.1
Suckermouth minnow	2			1	3	<0.1

Taxon	Electrofishing	Hoop Net	Mini-MO Trawl	Seine	Total	Percent Abundance
Chestnut lamprey	2				2	<0.1
Goldfish	2				2	<0.1
Gravel chub			2		2	<0.1
Unidentified sturgeons (Scaphirhynchus spp.)			2		2	<0.1
Unidentified temperate basses (Morone spp.)			1	1	2	<0.1
Unidentified fishes			2		2	<0.1
Banded killifish				1	1	<0.1
Black crappie	1				1	<0.1
Unidentified catfishes (Ictalurus spp.)			1		1	<0.1
Central stoneroller	1				1	<0.1
Creek chub				1	1	<0.1
Fathead minnow	1				1	<0.1
Johnny darter				1	1	<0.1
Largescale stoneroller	1				1	<0.1
Longear sunfish	1				1	<0.1
Unidentified madtoms (Noturus spp.)			1		1	<0.1
Silver lamprey	1				1	<0.1
Silver redhorse	1				1	<0.1
Silverband shiner			1		1	<0.1
Silvery minnow				1	1	<0.1
Spotted sucker	1				1	<0.1
Stonerollers				1	1	<0.1
Sucker - Catostominae			1		1	<0.1
Sucker - Catostomus			1		1	<0.1
Sucker - Redhorses			1		1	<0.1
Total	**5,659**	**437**	**7,546**	**11,623**	**25,265**	**100**
No. of species	**56**	**23**	**38**	**43**	**70**	
No. of hybrids	**2**	**2**	**1**	**2**	**2**	

Table 4-4 Percent Composition of Ichthyoplankton Collected from River Zones near the LEC During the 2017-2018 Biological Monitoring Study.

Taxon	Percent Composition			
	Zone 1 (Upstream Control)	Zone 3 (Thermally-exposed)	Zone 4 (Downstream)	All Zones
Silver/bighead carp	69.05	69.00	62.52	67.15
Unidentified Asian carp eggs	16.22	17.25	24.31	18.90
Grass carp	9.90	10.33	9.79	10.01
Freshwater drum	1.53	1.15	1.25	1.32
Unidentified carpsucker and buffalos (Ictiobinae subfamily)	1.79	1.23	0.69	1.28
Gizzard shad	0.63	0.35	0.48	0.49
Unidentified fishes	0.23	0.04	0.35	0.20
Blue sucker	0.10	0.20	0.14	0.14
Unidentified minnow family group 2	0.13	0.09	0.10	0.11
Unidentified carpsuckers (*Carpiodes* spp.)	0.06	0.07	0.10	0.07
Unidentified crappies (*Pomoxis* spp.)	0.05	0.07	0.01	0.05
Unidentified blacktail chubs (*Macrhybopsis* spp.)	0.06	0.02	0.01	0.03
Goldeye	0.04	0.02	0.04	0.03
Unidentified mooneyes (*Hiodon* spp.)	0.01	0.06	0.02	0.03
Unidentified minnow family group 4	0.03	0.01	0.04	0.03
Common carp	0.03	0.01	<0.01	0.02
Silver carp	0.01	0.01	0.03	0.02
Unidentified walleye/sauger (*Sander* spp.)	0.01	0.03	0.01	0.02
Unidentified minnow family group 3	<0.01	<0.01	0.05	0.02
Bighead carp	0.02	<0.01	0.01	0.01
Emerald shiner	0.02	0.01	0.01	0.01
Logperch	0.02	0.01	0.02	0.01
Unidentified minnow family	<0.01	<0.01	0.01	0.01
Mooneye	0.02	<0.01	<0.01	0.01
Unidentified sunfishes (*Lepomis* spp.)	0.01	<0.01	0.01	0.01

Taxon	Percent Composition			
	Zone 1 (Upstream Control)	Zone 3 (Thermally-exposed)	Zone 4 (Downstream)	All Zones
Unidentified temperate basses (*Morone* spp.)	0.01	0.01	<0.01	0.01
White bass	<0.01	0.01	0.02	0.01
Bluegill	<0.01	<0.01	<0.01	<0.01
Longnose gar	<0.01	<0.01	<0.01	<0.01
Unidentified shads (*Dorosoma* sp.)	<0.01	<0.01	<0.01	<0.01
Orangespotted sunfish	<0.01	0.01	<0.01	<0.01
Unidentified river sturgeons (*Scaphirhynchus* spp.)	<0.01	<0.01	<0.01	<0.01
Channel shiner	<0.01	<0.01	<0.01	<0.01

[1] Larval specimens in the carp and minnow family Cyprinidae that could not be identified to species were placed into six groupings based on four morphological characters including relative preanal length, eye shape, preanal myomere number, and midventral pigmentation according to Fuiman et al. (1983). Species belonging to each of the six Cyprinidae family groupings known to occur in the LMOR are summarized in Table A-1 of Appendix 4A.

4.4.3 PSPAP: Methodology and Results

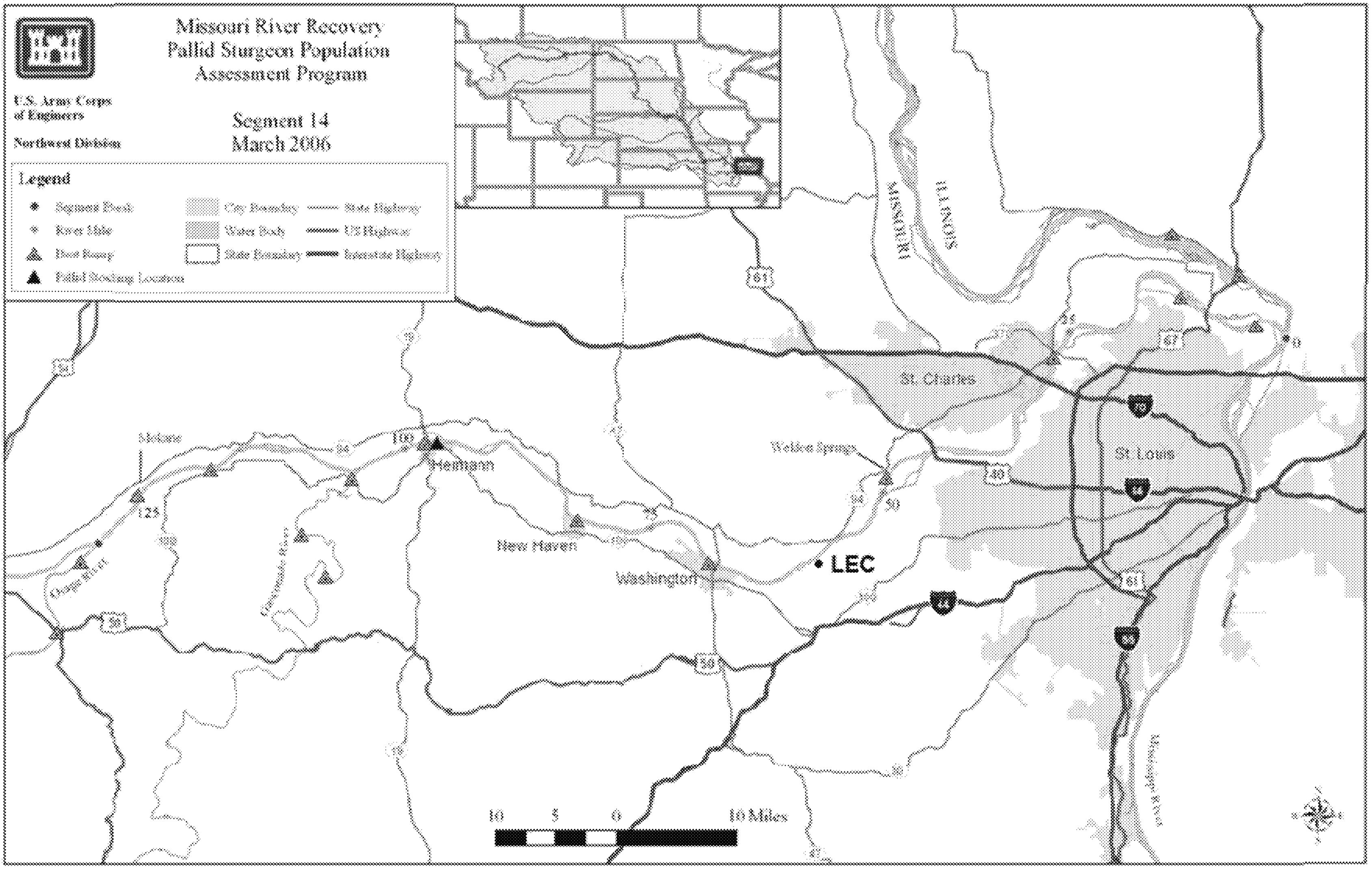
The most downstream segment surveyed as part of the PSPAP is Segment 14 (Figure 4-3), which includes the section of the river where the LEC is located as it spans 130 RM from the confluence with the Osage River (RM 130.2) to the confluence with the Mississippi River (RM 0.0). Each annual survey is divided into two seasons, sturgeon season and fish community season. Sturgeon season begins in the fall of the previous calendar year when water temperatures fall below 12.8°C and concludes at the end of June, and the fish community season occurs from July through October. Fourteen river bends within Segment 14 are randomly selected for sampling each year and five sampling gears are used to sample a range of habitats in proportion to their availability within each bend. Sampling gears include gill nets, otter trawls, trammel nets, mini-fyke nets, and trotlines. Specifications and additional information about each sampling gear are available in PSPAP annual reports for Segment 14 (Herman et al. 2014; Herman and Wrasse 2015, 2016).

Table 4-5 summarizes all fish caught in Segment 14 during regularly scheduled sampling (all gears combined) during the sturgeon and fish community seasons for 2013-2015 as reported in Appendix 4-F of each PSPAP annual report (Herman et al. 2014; Herman and Wrasse 2015, 2016). Sampling outside of the standard protocol frequently occurs as part of pallid sturgeon broodstock collection efforts as well as in response to river conditions that are unfavorable to the use of certain gears (e.g., additional trot lines replaced otter trawls during extended high-water events in 2015). Fish collected during these additional sampling events were not used for analysis in the annual reports, but presumably they account for discrepancies between total catches presented in the report text and those in Appendix 4-F.

Sampling effort was relatively consistent across survey years for four gears with deployments of gill nets ranging from 134-140, trotlines from 113-114, trammel nets from 109-112, and mini-fyke nets from 110-113. High-flow conditions prevented deployment of many otter trawls during the 2015 sturgeon season, when 153 trawls were deployed overall that year. In comparison, there were 240 and 232 trawls deployed in 2013 and 2014, respectively (Herman et al. 2014; Herman and Wrasse 2015, 2016).

The number of taxa collected within Segment 14 varied from 60 (58 species, 2 hybrids) in 2014 to 69 (67 species, 2 hybrids) in 2013 with a grand total of 85 unique taxa (83 species, 2 hybrids) observed across all three survey years (Table 4-5). The large total catch observed in 2013 (18,380 fish) was mostly explained by the increased collection of several shiners (red, channel, and emerald), gizzard shad, and goldeye in comparison to 2014 and 2015, when overall catches were lower (11,446 and 12,934 fish, respectively). Shovelnose sturgeon, blue catfish, red shiner, channel catfish, shoal chub, and gizzard shad were the most numerous species, collectively representing nearly 65 percent of the combined catch from all survey years. Another 11 taxa were moderately abundant (relative abundance between 1-5 percent).

Fifty-three pallid sturgeon, which is a federal-listed and Missouri state-listed endangered (S1) species (USFWS 2015), were caught in Segment 14 during all routine sampling conducted during the three survey years. Shovelnose sturgeon, which is listed as a federally-threatened species (USFWS 2010), was the most numerous species collected, which reflected a gear specificity for river sturgeons, the primary target of the sampling program. Also collected were 27 lake sturgeon, a state-listed endangered (S1) species in Missouri (MDC 2018). The majority of lake sturgeon caught during sampling were hatchery-stocked fish with coded wire tags. Additional species of state concern according to the MONHP ranking system collected in Segment 14 included two species assigned an S2 ranking, plains minnow and highfin carpsucker (*Carpiodes velifer*), as well as two species assigned an S3 ranking, sturgeon chub and river darter (*Percina shumardi*). Two species with SU rankings, skipjack herring and American eel, were also collected (Herman et al. 2014; Herman and Wrasse 2015, 2016).



Source: Herman et al. 2014, Herman and Wrasse 2015, Herman and Wrasse 2016.
LEC location is indicated by the black circle and label.

Figure 4-3 Segment 14 (RM 130.2-RM 0.0) of the Pallid Sturgeon Population Assessment Project.

Table 4-5 Fish Taxa Collected in Segment 14 Using All Sampling Gears During 2013-2015 of the PSPAP.

Taxon	2013	2014	2015	Total	Percent Abundance
Shovelnose sturgeon	3,537	3,582	3,235	10,354	24.2
Blue catfish	1,830	666	1,780	4,276	10.0
Red shiner	2,372	959	248	3,579	8.4
Channel catfish	1,225	1,144	1,084	3,453	8.1
Shoal chub	1,418	1,628	111	3,157	7.4
Gizzard shad	1,992	48	897	2,937	6.9
Freshwater drum	752	142	638	1,532	3.6
Channel shiner	1,201	175	88	1,464	3.4
Sicklefin chub	274	887	213	1,374	3.2
Emerald shiner	867	216	91	1,174	2.7
Unidentified sunfishes (*Lepomis* spp.)	209	2	830	1,041	2.4
Longnose gar	276	173	371	820	1.9
Blue sucker	211	251	247	709	1.7
White crappie	22		503	525	1.2
Goldeye	434	46	26	506	1.2
Bullhead minnow	177	100	206	483	1.1
Orangespotted sunfish	15	84	349	448	1.0
Bluegill	48	37	301	386	0.9
Silver carp	56	272	18	346	0.8
Unidentified fish		5	332	337	0.8
Silver chub	132	55	137	324	0.8
Western mosquitofish	33	62	205	300	0.7
Unidentified Cyprinidae	93	123	19	235	0.5
Shortnose gar	109	57	64	230	0.5
Unidentified Centrarchidae	4	63	162	229	0.5
Sturgeon chub	93	99	30	222	0.5
River carpsucker	115	50	41	206	0.5
Unidentified Catostomidae	192	4	3	199	0.5
Unidentified chub	95	65	21	181	0.4
Smallmouth buffalo	47	50	64	161	0.4
Unidentified buffalo		77	50	127	0.3
Unidentified taxon UIC	50	36	22	108	0.3
Bluntnose minnow	36	14	49	99	0.2
Sand shiner	12	35	32	79	0.2
Sauger	28	33	17	78	0.2
Flathead catfish	20	16	32	68	0.2
Common carp	20	11	33	64	0.1
White bass	35	2	25	62	0.1
Unidentified sturgeons (*Scaphirhynchus* spp.)	21		39	60	0.1
Pallid sturgeon	10	17	26	53	0.1
Young-of-Year (YOY) Fish	26	6	19	51	0.1
Shorthead redhorse	26	13	11	50	0.1
Unidentified silvery minnows (*Hybognathus* spp.)	9	5	34	48	0.1
Paddlefish	28	14	3	45	0.1
Plains minnow		9	31	40	0.1
Green sunfish	8		31	39	0.1
Grass carp	11	16	11	38	0.1
River shiner	27	3	7	37	0.1
Unidentified shiner	34			34	0.1
Unidentified carpsuckers (*Carpiodes* spp.)	32			32	0.1
Lake sturgeon	14	8	5	27	0.1

Taxon	2013	2014	2015	Total	Percent Abundance
Spotted sunfish	8	3	15	26	0.1
Stonecat	6	15	3	24	0.1
Pallid sturgeon × shovelnose sturgeon	8	8	7	23	0.1
Unidentified *Ictalurus* spp.	3		17	20	<0.1
Brook silverside	12	1	6	19	<0.1
Unidentified taxon “UTB” [1]		13	2	15	<0.1
Unidentified taxon “UPP” [1]	3	9		12	<0.1
Black buffalo	7	3	2	12	<0.1
Unidentified taxon “UHR” [1]			12	12	<0.1
Fathead minnow	2		10	12	<0.1
Black crappie	1	1	9	11	<0.1
Logperch	2		9	11	<0.1
Quillback	5	2	3	10	<0.1
Largemouth bass	3		7	10	<0.1
Unidentified redhorse	3		6	9	<0.1
Unidentified Asian carp	4	2		6	<0.1
Chestnut lamprey	2	1	3	6	<0.1
Blackspotted topminnow	1	4		5	<0.1
Spotfin shiner	2	3		5	<0.1
Golden redhorse	4	1		5	<0.1
Unidentified taxon “BTTM” [1]	1	2	1	4	<0.1
Striped bass × white bass	1	1	2	4	<0.1
Unidentified *Catostomus* spp.			4	4	<0.1
Yellow bullhead	3		1	4	<0.1
Bigeye shiner	4			4	<0.1
Black bullhead		1	2	3	<0.1
Johnny darter	1	1	1	3	<0.1
Unidentified taxon “BLCP” [1]			3	3	<0.1
Unidentified taxon “RFSN” [1]			3	3	<0.1
Golden shiner	2		1	3	<0.1
Skipjack herring	2		1	3	<0.1
Blackside darter		2		2	<0.1
Gravel chub		2		2	<0.1
Unidentified taxon “WSMW” [1]		2		2	<0.1
Goldfish		1	1	2	<0.1
Northern hog sucker	1	1		2	<0.1
River darter	1	1		2	<0.1
River redhorse	1	1		2	<0.1
Spotted gar	1	1		2	<0.1
Central stoneroller			2	2	<0.1
Striped bass	1		1	2	<0.1
Walleye	1		1	2	<0.1
Slenderhead darter	2			2	<0.1
Banded darter		1		1	<0.1
Highfin carpsucker		1		1	<0.1
Unidentified darter		1		1	<0.1
Yellow bass		1		1	<0.1
American eel			1	1	<0.1
Bighead carp			1	1	<0.1
Common shiner			1	1	<0.1
Mimic shiner			1	1	<0.1
Mooneye			1	1	<0.1
Tadpole madtom			1	1	<0.1
Unidentified taxon “UGR” [1]			1	1	<0.1

Taxon	2013	2014	2015	Total	Percent Abundance
Warmouth			1	1	<0.1
Bigmouth buffalo	1			1	<0.1
Freckled madtom	1			1	<0.1
Missouri saddled darter	1			1	<0.1
Suckermouth minnow	1			1	<0.1
Unidentified Percidae	1			1	<0.1
White sucker	1			1	<0.1
Total	**18,380**	**11,446**	**12,934**	**42,760**	**100.0**
No. of species	**67**	**58**	**64**	**83**	
No. of hybrids	**2**	**2**	**2**	**2**	

Source: Herman et al. 2014, Herman and Wrasse 2015, 2016.

[1] Taxa reported in Appendix 4-F Tables of the PSPAP annual reports (Herman et al. 2014, Herman and Wrasse 2015, 2016) were listed by letter codes that were identified in Appendix 4-A of those reports. Taxa with letter codes not found in Appendix 4-A are listed here as "Unidentified taxon" followed by respective letter codes. These taxa were not included in species richness counts.

4.4.4 BFS: Methodology and Results

Segments of the Missouri River sampled as part of the BFS were distributed among three zones: the least-altered zone, which included the downstream reach of the Yellowstone River and portions of the Missouri River upstream of Fort Peck Lake; the inter-reservoir zone comprised of free-flowing reaches below the Fork Peck, Garrison, Fort Randall, and Gavins Point dams; and the channelized zone from Sioux City, Iowa to the confluence with the Mississippi River. Segments 25 (RM 220-RM 130) and 27 (RM 50-RM 0) in the channelized zone were in closest proximity to the LEC (Figure 4-4), being located upstream and downstream of the facility, respectively (Berry and Young 2001).

Five sampling gears were used to avoid gear selectivity when sampling six macrohabitat categories, including channel crossovers, inside and outside bends, tributary mouths, and connected and non-connected secondary channels. Gears included the use of gill nets, trammel nets, bag seines, benthic trawls, and pulsed-DC electrofishing. A stratified random sampling design was employed each year to select five sites of each macrohabitat for sampling within each segment. However, river conditions often affected availability of each habitat, limiting the number of replicates that could be sampled. Specifications and additional information about each sampling gear and the study design are outlined in Berry et al. (2004).

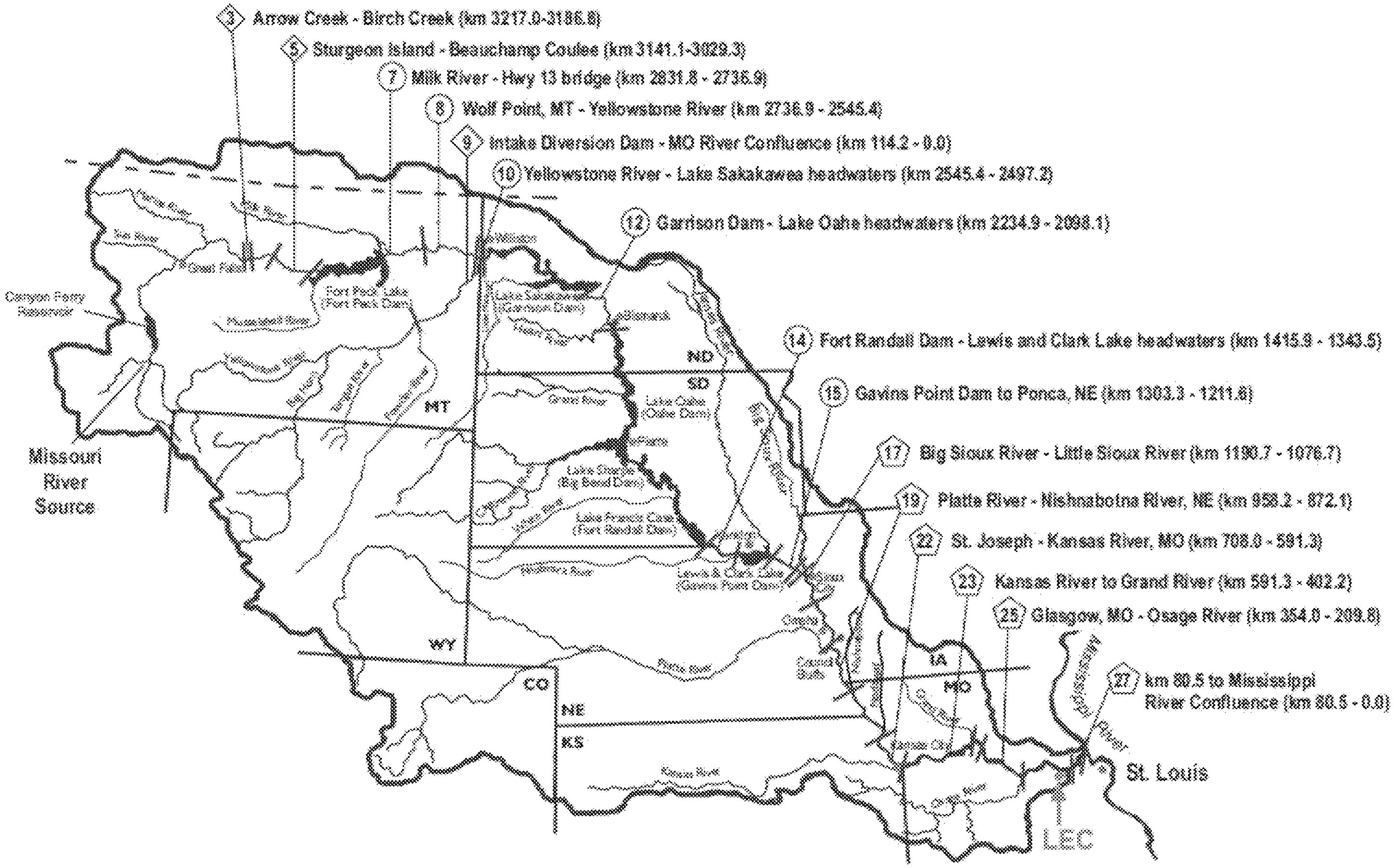
A total of 15 river bends and 25 connected secondary channels were sampled during the three survey years in segments 25 and 27. However, one non-connected secondary channel and 19 tributary mouth habitats were sampled in Segment 25, whereas 15 non-connected secondary channels and 11 tributary mouth habits were sampled in Segment 27 (Berry et al. 2004).

The number of species collected from the combined catches made in segments 25 and 27 varied from 38 in 1996 to 63 in 1997 with a grand total of 68 unique species observed across all three survey years (Table 4-6). The reduced catch observed in 1996 (3,258 fish) relative to 1997 (14,045 fish) and 1998 (8,833 fish) occurred in all segments of the BFS and was explained by modifications in sampling procedures that increased seining, electrofishing, and gill netting effort during the latter two survey years. Increased collection of gizzard shad, river carpsucker, and unidentified silvery minnows (*Hybognathus* spp.) accounted for the larger catch observed in 1997 relative to 1998. These taxa along with emerald shiner, red shiner, and channel catfish were the most numerous fishes collected, representing approximately 82 percent of the combined catch from all survey years. Freshwater drum, common carp, flathead catfish, bluegill (*Lepomis macrochirus*), and speckled chub[1] were collected in moderate abundance.

Twenty-three species were either primarily or exclusively collected from segments 25 and 27 as indicated by greater than 50 percent of individuals caught during the entire BFS occurring in these sections (Table 4-6). Among rare species that were exclusively found in the lowermost reaches of the river were the freckled madtom (*Noturus nocturnus*), yellow bass (*Morone mississippiensis*), Missouri state-endangered lake sturgeon, chestnut lamprey (*Ichthyomyzon castaneus*), common shiner (*Luxilus cornutus*), largescale stoneroller (*Campostoma oligolepis*), bowfin (*Amia calva*), striped shiner (*Luxilus chrysocephalus*), and longear sunfish (*Lepomis megalotis*). More common species concentrated in this region of the river were the red shiner, blue catfish, and speckled (shoal) chub. Species commonly collected during the BFS which were present at notably low densities in segments 25 and 27 included the Missouri state-endangered flathead chub (*Platygobio gracilis*), sturgeon chub, quillback (*Carpiodes cyprinus*), white crappie (*Pomoxis annularis*), shorthead redhorse (*Moxostoma macrolepidotum*), fathead minnow (*Pimephales promelas*), sauger, bigmouth buffalo (*Ictiobus cyprinellus*), walleye (*Sander vitreus*), northern pike (*Esox lucius*), and stonecat (*Noturus flavus*). Thirty-eight species collected during the BFS were not present in segments 25 and 27.

Federal and state-listed species collected from segments 25 and 27 were the federally-threatened shovelnose sturgeon (USFWS 2010) and two Missouri state-endangered (S1) species, the lake sturgeon and flathead chub (MDC 2018). Neither state-listed species was collected in abundance (five or fewer individuals). Lake sturgeon was only collected from these segments during the BFS, whereas flathead chub occurred at high densities in upstream reaches of the Missouri River above the Garrison Dam (Berry et al. 2004). Additional species of state concern according to the MONHP ranking system collected in Segment 14 included three species assigned an S2 ranking, plains minnow, highfin carpsucker, and ghost shiner, as well as one species assigned an S3 ranking, which was sturgeon chub. One species with an SU ranking, skipjack herring, was also collected.

[1] All specimens formerly identified as speckled chub are now identified as shoal chub.



Source: Berry and Young 2001.

Diamond labels indicate segments in the least-altered zone, circles the inter-reservoir zone, and pentagons the channelized zone. Segments 25 (RM 220-RM 130) and 27 (RM 50-RM 0) were located upstream and downstream of the LEC (orange circle), respectively.

Figure 4-4 Location of River Segments Surveyed Using Multiple Sampling Gears as Part of the Benthic Fishes Study (1996-1998).

Table 4-6 Number and Percent Abundance of Fish Taxa Collected from Segments 25 and 27 During 1996-1998 BFS Sampling, Total BFS Survey Catch, and Percentage of the Total Catch Represented by Segment 25 and 27 Collections.

	Segments 25 and 27					Entire BFS	
Taxon	1996	1997	1998	Total	Percent Abundance	Total[1]	Percent in Segments 25 and 27
Gizzard shad	1,529	4,531	2,874	8,934	34.2	25,927	34.5
Emerald shiner	301	1,851	1,912	4,064	15.5	20,362	20.0
Unidentified silvery minnows (*Hybognathus* spp.)	164	2,080	764	3,008	11.5	12,718	23.7
River carpsucker	46	2,201	219	2,466	9.4	6,688	36.9
Red shiner	81	672	955	1,708	6.5	2,382	71.7
Channel catfish	254	506	518	1,278	4.9	5,656	22.6
Freshwater drum	256	210	241	707	2.7	2,770	25.5
Common carp	93	218	138	449	1.7	3,037	14.8
Flathead catfish	102	82	149	333	1.3	1,456	22.9
Bluegill	44	205	53	302	1.2	671	45.0
Speckled chub[1]	5	215	32	252	1.0	326	77.3
Shortnose gar	45	131	55	231	0.9	614	37.6
Goldeye	81	83	51	215	0.8	4,014	5.4
Blue catfish	81	34	95	210	0.8	382	55.0
Western mosquitofish	5	107	96	208	0.8	227	91.6
Sand shiner	19	90	95	204	0.8	693	29.4
Shovelnose sturgeon	13	62	109	184	0.7	1,560	11.8
Sicklefin chub	15	37	93	145	0.6	709	20.5
River shiner	1	124	10	135	0.5	876	15.4
White bass	6	86	16	108	0.4	542	19.9
Silver chub	28	64	11	103	0.4	423	24.3
Mimic shiner		57	33	90	0.3	100	90.0
Longnose gar	16	28	35	79	0.3	185	42.7
Smallmouth buffalo	6	46	20	72	0.3	485	14.8
Unidentified fishes		28	39	67	0.3	131	51.1
Unidentified shiners		5	51	56	0.2	396	14.1
Spotted bass		41	14	55	0.2	58	94.8
Unidentified minnows	1	23	29	53	0.2	721	7.4
Bluntnose minnow	3	19	16	38	0.1	42	90.5
Green sunfish	3	18	13	34	0.1	210	16.2
Largemouth bass	11	19	1	31	0.1	314	9.9
Sauger	6	15	6	27	0.1	614	4.4
White crappie	13	9	2	24	0.1	1,480	1.6
Orangespotted sunfish	3	11	9	23	0.1	127	18.1

[1] The shoal chub was elevated to full species status from the speckled chub species-complex through morphological studies by Eisenhour (1999, 2004) and genetic studies by Underwood et al. (2003). Henceforth, all specimens formerly identified as speckled chub are now identified as shoal chub.

Taxon	Segments 25 and 27					Entire BFS	
	1996	1997	1998	Total	Percent Abundance	Total[1]	Percent in Segments 25 and 27
Bigmouth shiner		18	3	21	0.1	109	19.3
Plains minnow		20		20	0.1	57	35.1
Striped bass	15	5		20	0.1	21	95.2
Bighead carp	2	3	9	14	0.1	22	63.6
Sturgeon chub	2	9	3	14	0.1	2,051	0.7
Stonecat			11	11	<0.1	342	3.2
Unidentified chubs		2	9	11	<0.1	16	68.8
Shorthead redhorse		7	4	11	<0.1	1,200	0.9
Brook silverside		2	7	9	<0.1	16	56.3
Quillback		7	2	9	<0.1	1,962	0.5
Skipjack herring		7	2	9	<0.1	10	90.0
Freckled madtom		3	5	8	<0.1	8	100.0
Blue sucker		1	6	7	<0.1	200	3.5
Bigmouth buffalo	1	5	1	7	<0.1	517	1.4
Yellow bass		4	2	6	<0.1	6	100.0
Black crappie		5	1	6	<0.1	199	3.0
Suckermouth minnow	2	4		6	<0.1	10	60.0
Paddlefish		1	4	5	<0.1	15	33.3
Lake sturgeon		4	1	5	<0.1	5	100.0
Bigeye shiner		1	3	4	<0.1	5	80.0
Grass carp		3	1	4	<0.1	13	30.8
Flathead chub	1	2	1	4	<0.1	12,838	<0.1
Bullhead minnow		4		4	<0.1	11	36.4
Logperch		4		4	<0.1	5	80.0
Highfin carpsucker		2	1	3	<0.1	6	50.0
Walleye	1	2		3	<0.1	441	0.7
Chestnut lamprey		2		2	<0.1	2	100.0
Common shiner		2		2	<0.1	2	100.0
Largescale stoneroller		2		2	<0.1	2	100.0
Fathead minnow	1	1		2	<0.1	739	0.3
Bowfin			1	1	<0.1	1	100.0
Larval fishes			1	1	<0.1	63	1.6
Northern pike			1	1	<0.1	368	0.3
Johnny darter		1		1	<0.1	130	0.8
Rainbow smelt		1		1	<0.1	23	4.3
Silverband shiner		1		1	<0.1	2	50.0
Spotted gar		1		1	<0.1	2	50.0
Striped shiner		1		1	<0.1	1	100.0
Ghost shiner	1			1	<0.1	2	50.0
Longear sunfish	1			1	<0.1	1	100.0
All other fishes in BFS	--	--	--	--	--	15,844	0.0

Taxon	Segments 25 and 27					Entire BFS	
	1996	1997	1998	Total	Percent Abundance	Total[1]	Percent in Segments 25 and 27
Total	**3,258**	**14,045**	**8,833**	**26,136**	**100.0**	**134,163**	
No. of species	**38**	**63**	**51**	**68**		**106**	

Source: Berry et al. 2004.

4.4.5 Impingement Abundance Monitoring

Impingement sampling was conducted at the LEC intake over a 12-month period from 8 August 1974 through 10 July 1975. Sampling was conducted at bimonthly intervals as fish washed from the intake screens were collected over 24-hour periods using removable screens placed within the two sub-floor level washwater sluices located in front of and behind the traveling screens. A total of 2,117 fish and 26.7 kilograms of biomass representing 18 identifiable species were collected (Table 4-7). Total impingement during the study period was estimated to be approximately 20,869 fish and 309.8 kilograms. Gizzard shad and freshwater drum accounted for approximately 95 and 87 percent of impinged fish and fish biomass, respectively. Monthly estimates of the number of fish impinged ranged from 13 fish in June 1975 to 4,718 fish in February 1975, whereas monthly estimates of impinged biomass ranged from 0.3 kilograms in June 1975 to 91.7 kilograms in August 1974 (EEHI 1976a).

The most recent impingement monitoring at the LEC was conducted over a one-year period from 13 July 2005 through 13 July 2006. Impinged fish were collected biweekly in a composite impingement sample that was collected over a continuous 24-hour sampling period. Traveling screens were rotated immediately prior to the start of the 24-hour collection to remove previously impinged fish and debris, and then were rotated as necessary during the collection period to maintain an acceptable head differential according to normal CWIS operating procedures. Impinged fish were collected in a specially constructed 4-foot x 4-foot x 4-foot metal frame basket with 3/8-in. woven mesh and 1/4-in. nylon net liner that was placed by a jib crane beneath the floor where the screen washwater exits the screenhouse prior to being returned to the river. Impinged specimens collected during the screen washes were processed for species identification and length and weight measurements (ASA and Alden 2008).

There were 26 sampling occasions at the LEC during the 2005-2006 impingement monitoring period. A total of 6,972 fish and 72.2 kilograms of biomass representing 35 species were collected (Table 4-7). Total impingement during the study period was estimated to be approximately 100,926 fish and 1,143 kilograms. Gizzard shad and freshwater drum accounted for approximately 93 and 81 percent of impinged fish and fish biomass respectively. Catfishes (blue, channel, and flathead) were also relatively abundant, collectively representing approximately 5 and 6 percent of impinged fish and fish biomass, respectively. Although not numerically abundant, shovelnose sturgeon (n=11) accounted for 7 percent of impinged biomass (ASA and Alden 2008).

The great majority of impinged fish were less than 150–175 mm in length. At least 92 percent of the total annual impingement consisted of young-of-year (YOY) fish based on measured fish lengths and life history data for fishes in the LMOR or Missouri waters. Impingement was highest in August and September, when the 2005 year class began to be recruited to collections and YOY and yearling fish dominated impingement collections (ASA and Alden 2008).

Federal and state-listed species collected during impingement monitoring were the federally-threatened shovelnose sturgeon (USFWS 2010) and the Missouri state-endangered lake sturgeon (MDC 2018). All nine lake sturgeon were collected on 7 September 2005 and were verified to have been hatchery-reared fish tagged by the MDC and stocked approximately 10 miles upstream from the LEC on 2 September 2005 (Danny Brown, MDC, personal communication). These released fish may have schooled and concentrated temporarily near the LEC CWIS, resulting in an anomalous impingement event unlikely to be reflective of actual rates of impingement of the species (ASA and Alden 2008). A single sturgeon chub, which is assigned an S3 ranking according to the MONHP system, was collected during 2005-2006 monitoring. Skipjack herring, which has an SU ranking, also was collected during 2005-2006.

Organisms impinged other than fish included invertebrates such as crayfish (n=117), Asian clams (*Corbicula* spp., n=683) and freshwater mussels in the Lampsilinae subfamily (n=8), and vertebrates such as turtles (4) and frogs (1). Most were Asian clams (83 percent), an introduced nuisance species.

4.4.1 Entrainment Characterization Study

A two-year entrainment characterization study was conducted at the LEC during 2015 and 2016 to meet the requirements imposed under § 122.21(r)(9). Sampling was performed weekly from March through September to coincide with the period when entrainment of fish eggs and larvae was most likely to occur. Samples were collected every 6 hours over a 24-hour period using a pump-and-net barrel sampler fitted with a conical 335-μm mesh ichthyoplankton net to collect specimens from water pumped from the discharge seal well. Each sample was collected from approximately 100 cubic meters of water as an inline flow meter was used to calculate the volume of water filtered. Flow rates were less than one cubic meter per minute and nets were switched halfway through each sample to minimize damage to specimens. Specimens were sorted in the laboratory and a Folsom plankton splitter was used to divide samples into subsamples when a large number of specimens or detritus were present. Subsamples were processed until a minimum of 200 identifiable specimens were found.

A total of 70,704 fish eggs, larvae, juveniles, and adults representing 10 families and 14 identifiable species was collected during 2015 entrainment sampling conducted at the LEC discharge (Table 4-8). Asian carp in the genus *Hypophthalmichthys*, (silver carp and bighead carp) and grass carp accounted for 84 percent of all collected specimens. Carps and minnows in the Cyprinidae family, gizzard shad, freshwater drum, carpsuckers and buffalos in the subfamily Ictiobinae, and goldeye accounted for the majority of all remaining specimens.

A total of 49,986 fish eggs, larvae, juveniles, and adults representing 11 families and 15 identifiable species was collected during 2016 entrainment sampling (Table 4-8). Asian carp again dominated the total collection, representing 85 percent of all specimens. Carps and minnows in the Cyprinidae family, freshwater drum, fishes that could not be identified to any taxonomic level, carpsuckers and buffalos in the subfamily Ictiobinae, and carpsuckers in the genus *Carpiodes* collectively accounted for another 12 percent of collected specimens.

No federal or state-listed species were identified among specimens collected during either year.

Additional details on the site-specific entrainment sampling conducted at the LEC can be found within the § *122.21(r)(9) Entrainment Characterization Study* submittal.

Table 4-7 Number and Biomass of Fish Taxa Collected During Impingement Monitoring Conducted During 1974-1975 and 2005-2006 at the LEC.

Taxon	Number of Fish				Biomass (g)			
	1974-1975	Percent	2005-2006	Percent	1974-1975	Percent	2005-2006	Percent
Gizzard shad	1,719	81.2	4,459	64.0	20,385	76.4	43,879	60.8
Freshwater drum	289	13.7	2,003	28.7	2,691	10.1	14,733	20.4
Blue catfish	15	0.7	140	2.0	180	0.7	1,531	2.1
Channel catfish	14	0.7	119	1.7	118	0.4	1,498	2.1
Flathead catfish	21	1.0	76	1.1	106	0.4	1,367	1.9
Bluegill	7	0.3	28	0.4	60	0.2	281	0.4
Goldeye			28	0.4			1,644	2.3
Common carp	4	0.2	17	0.2	1,810	6.8	936	1.3
Shovelnose sturgeon			11	0.2			5,119	7.1
Skipjack herring			10	0.1			296	0.4
Lake sturgeon			9	0.1			90	0.1
Stonecat	1	0.0	7	0.1	5	<0.1	89	0.1
Golden redhorse			6	0.1			49	0.1
Emerald shiner			5	0.1			15	<0.1
Green sunfish			5	0.1			96	0.1
Shorthead (Northern) redhorse	2	0.1	5	0.1	135	0.5	51	0.1
Silver carp			5	0.1			54	0.1
Red shiner			4	0.1			12	<0.1
Redfin shiner			4	0.1			9	<0.1
Rock bass	3	0.1	3	<0.1	50	0.2	16	<0.1
White bass	3	0.1	3	<0.1	95	0.4	22	<0.1
Freckled madtom			3	<0.1			26	<0.1
Quillback			3	<0.1			229	0.3
Bighead carp			2	<0.1			16	<0.1
Blue sucker			2	<0.1			6	<0.1
Largemouth bass			2	<0.1			25	<0.1
Mooneye			2	<0.1			27	<0.1
Sauger			2	<0.1			53	0.1
White crappie	5	0.2	1	<0.1	30	0.1	2	<0.1

Taxon	Number of Fish				Biomass (g)			
	1974-1975	Percent	2005-2006	Percent	1974-1975	Percent	2005-2006	Percent
River carpsucker	2	0.1	1	<0.1	20	0.1	5	<0.1
Unidentified minnows	2	0.1	1	<0.1		<0.1	1	<0.1
Bullhead minnow			1	<0.1			3	<0.1
Goldfish			1	<0.1			7	<0.1
Speckled (shoal) chub			1	<0.1			4	<0.1
Sturgeon chub			1	<0.1			3	<0.1
Unidentified carpsuckers			1	<0.1			2	<0.1
Warmouth			1	<0.1			8	<0.1
Chestnut lamprey	11	0.5			657	2.5		
Unidentified catfishes	9	0.4			--	--		
Black bullhead	4	0.2			255	1.0		
Striped bass	2	0.1			16	0.1		
Longnose gar	1	<0.1				<0.1		
Mimic shiner	1	<0.1			1	<0.1		
Unidentified black basses	1	<0.1			18	0.1		
Unidentified bullheads	1	<0.1			48	0.2		
Total	**2,117**		**6,972**		**26,680**		**72,204**[2]	
No. of species	**18**[1]		**35**					

Source: EEHI 1976a, ASA & Alden 2008.

[1] 20 species reported in EEHI 1976a.
[2] 72,201 g reported in ASA and Alden 2008.

Table 4-8 Number of Fish Taxa by Life Stages Collected During Entrainment Abundance Monitoring Conducted During 2015 and 2016 at the LEC.

2015 Study Year								
Taxon	Eggs	YSL[1]	PYSL[2]	LAR[3]	Juveniles	Adults	Total	Percent
Silver and bighead carp	--	2,782	30,202	26,408	9	0	59,401	84.0
Unidentified fishes	192	0	1,115	5,181	2	0	6,490	9.2
Minnow family	--	8	185	1,621	0	0	1,814	2.6
Gizzard shad	--	0	715	304	50	0	1,069	1.5
Freshwater drum	114	0	313	147	2	0	576	0.8
Carpsuckers and buffalos	--	107	125	55	0	0	287	0.4
Goldeye	--	97	148	0	4	0	249	0.4
Grass carp	--	120	49	0	0	0	169	0.2
Shads	--	0	41	128	0	0	169	0.2
Common carp	--	2	84	12	20	0	118	0.2
Buffalos	--	41	22	8	2	0	73	0.1
Carpsuckers	--	35	23	0	0	0	58	0.1
Minnows group 2	--	0	38	0	0	0	38	0.1
Sucker family	--	0	1	35	0	0	36	0.1
Walleye	--	0	32	1	0	0	33	0.1
Redhorse suckers	--	10	14	4	0	0	28	<0.1
Mooneyes (*Hiodon* sp.)	--	0	16	8	0	0	24	<0.1
White sucker	--	2	15	3	0	0	20	<0.1
Sunfish family	--	0	13	0	1	0	14	<0.1
Crappies	--	0	0	0	8	0	8	<0.1
Channel catfish	--	0	2	1	3	0	6	<0.1
Silver carp	--	0	4	0	1	0	5	<0.1
Shortnose gar	--	0	0	4	0	0	4	<0.1
Walleye and sauger	--	0	4	0	0	0	4	<0.1
White bass	--	0	2	0	2	0	4	<0.1
White crappie	--	0	2	0	0	0	2	<0.1
Blue catfish	--	0	1	0	0	0	1	<0.1
North American catfish family	--	0	1	0	0	0	1	<0.1
Minnows group 5	--	0	1	0	0	0	1	<0.1
Minnows group 6	--	0	1	0	0	0	1	<0.1
Shoal chub	--	0	0	0	0	1	1	<0.1
Study Year Total	**306**	**3,204**	**33,169**	**33,920**	**104**	**1**	**70,704**	**100.0**
2016 Study Year								
Taxon	Eggs	YSL[1]	PYSL[2]	LAR[3]	Juveniles	Adults	Total	Percent
Silver and bighead carp	6	28,143	276	11,505	0	0	39,930	79.9
Minnow family	--	1	2	3,645	0	0	3,648	7.3
Grass carp	--	2,434	113	75	0	0	2,622	5.3
Freshwater drum	38	609	282	91	1	0	1,021	2.0
Unidentified fishes	711	14	1	190	1	0	917	1.8
Carpsuckers and buffalos	--	150	179	385	0	0	714	1.4
Carpsuckers	--	184	51	17	0	0	252	0.5
Gizzard shad	--	0	107	40	10	0	157	0.3
Mooneyes (*Hiodon* sp.)	--	13	16	128	0	0	157	0.3
Buffalos	--	102	34	0	0	0	136	0.3
Common carp	--	33	56	8	4	0	101	0.2

Taxon	Eggs	YSL[1]	PYSL[2]	LAR[3]	Juveniles	Adults	Total	Percent
Goldeye	--	93	1	1	0	0	95	0.2
Minnows group 2	--	20	12	8	0	0	40	0.1
White bass	--	32	0	0	0	0	32	0.1
Mooneye	--	26	1	2	0	0	29	0.1
Blue sucker	--	12	5	8	0	0	25	0.1
Sunfishes (*Lepomis* sp.)	--	2	14	0	2	0	18	<0.1
Sucker family	--	0	0	16	0	0	16	<0.1
White sucker	--	0	2	12	0	0	14	<0.1
Shads	--	0	0	10	0	0	10	<0.1
Blue catfish	--	1	3	3	2	0	9	<0.1
Redhorse suckers	--	1	5	0	0	0	6	<0.1
Walleye and sauger	--	2	4	0	0	0	6	<0.1
Minnows group 6	--	0	3	2	0	0	5	<0.1
Darters (*Etheostoma* sp.)	--	1	2	0	0	0	3	<0.1
Logperch	--	1	1	1	0	0	3	<0.1
Minnows group 3	--	0	3	0	0	0	3	<0.1
Minnows group 4	--	1	2	0	0	0	3	<0.1
Sunfish family	--	0	3	0	0	0	3	<0.1
Catfishes (*Ictalurus* sp.)	--	0	0	0	2	0	2	<0.1
Crappies	--	0	2	0	0	0	2	<0.1
Darters (*Percina* sp.)	--	1	0	0	0	0	1	<0.1
Paddlefish	--	0	0	1	0	0	1	<0.1
Redhorses and white sucker	--	0	1	0	0	0	1	<0.1
Western mosquitofish	--	0	0	0	0	1	1	<0.1
Walleye	--	0	1	0	0	0	1	<0.1
Channel catfish	--	0	0	0	1	0	1	<0.1
North American catfish family	--	1	0	0	0	0	1	<0.1
Study Year Total	**755**	**31,877**	**1,182**	**16,148**	**23**	**1**	**49,986**	**100.0**
Grand Total	**1,061**	**35,081**	**34,351**	**50,068**	**127**	**2**	**120,69**	--
No. of Families	**2**	**8**	**9**	**9**	**8**	**2**	**12**	--
No. of Species	**1**	**10**	**15**	**14**	**16**	**2**	**19**	--

Larval specimens in the carp and minnow family Cyprinidae grouped based on four morphological characters according to Fuiman et al. (1983). See Table A-1 of Appendix 4A.

[1] YSL = yolk-sac larvae
[2] PYSL = post yolk-sac larvae
[3] LAR = larvae of indistinguishable stages of development

4.4.2 Spatial Distribution and Temporal Abundance of Species

Large-scale comparisons of how relative abundance of fish species varied within the reaches of the LMOR near the LEC were made by contrasting catches of the most abundant fishes between segments 25 and 27 of the BFS (1996-1998) and based on observations of pallid and lake sturgeon made during recent PSPAP (2013-2015) sampling. The 2017-2018 biological monitoring program (ASA 2019) at the LEC allowed both an evaluation of near-field spatial distribution and a determination of seasonal patterns of fish abundance in the vicinity of the LEC. Additional temporal patterns were made based on the one-year impingement monitoring study conducted from July 2005 through July 2006 (ASA and Alden 2008), the two-year entrainment characterization study conducted during 2015 and 2016, and a study investigating diel drift patterns of fish larvae in the LMOR conducted during 2002 (Reeves and Galat 2010).

4.4.2.1 Spatial Variation

Segment 25 (RM 220-RM 130) of the BFS (Berry et al. 2004) terminated more than 70 miles upstream of the LEC, whereas Segment 27 (RM 50-RM 0) began 7.5 miles downstream of the facility. Therefore, Segment 27 was more likely to be representative of the fish community present at the LEC at the time of sampling (1996-1998). Comparisons were limited to taxa that were collected in numbers greater than 200 individuals over the study period when combining catches from both segments. Differences were considered notable if the relative difference in total catches made during the study period was greater than 30 percent during at least two of the three survey years.

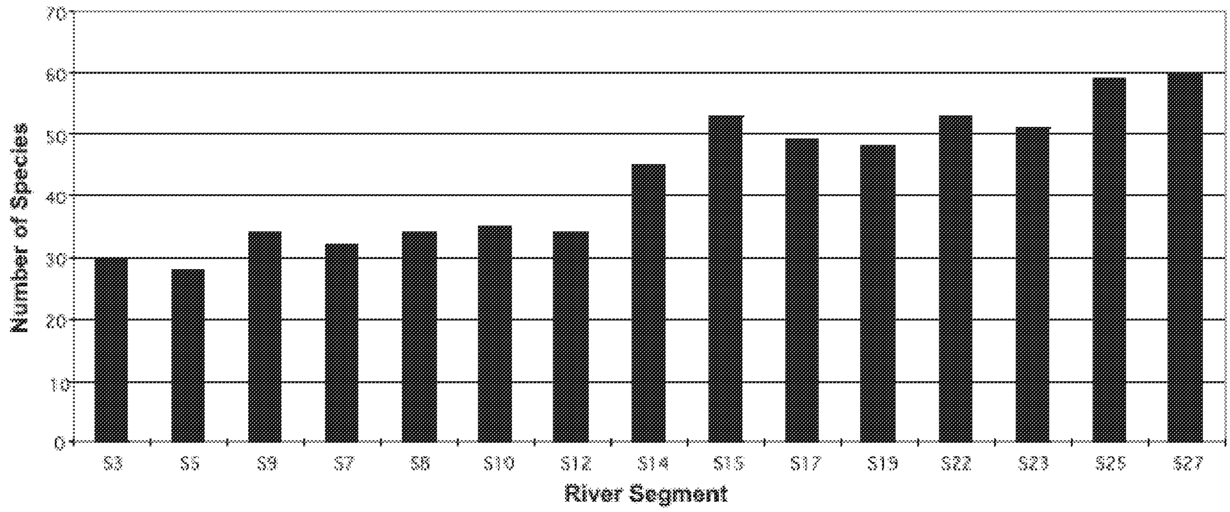
Species richness tended to increase when moving downstream during the BFS (Berry et al. 2004) and segments 25 and 27 were the most species-rich segments sampled (Figure 4-5). Annual catches made in Segment 27 tended to be larger than those from Segment 25 as the relative difference (expressed relative to Segment 25) of the total catch was approximately 29 percent (Table 4-9). Of the 14 taxa collected in adequate numbers for comparison between segments, eight had notably different densities between the sections. Red shiner, gizzard shad, speckled chub, and shortnose gar were more abundant in Segment 27, whereas goldeye, bluegill, emerald shiner, and unidentified silvery minnows (*Hybognathus* species) were more abundant in Segment 25. Densities of catfishes (blue, channel, and flathead), common carp, and freshwater drum were similar between the segments, although abundances occasionally differed during individual years.

Only two of 73 pallid sturgeon collected from Segment 14 during recent (2013-2015) PSPAP sampling (including collections made outside of regularly-scheduling sampling activities) were caught within 10 RM of the LEC (Figure 4-6). The lower 40 RM of the segment have historically low catch rates of pallid sturgeon (Herman et al. 2014; Herman and Wrasse 2015, 2016). The vast majority of pallid sturgeon were collected upstream of RM 100 with the highest concentrations located near major tributary confluences with the Osage River at RM 130.2 and the Gasconade River at RM 105. Many of the state-endangered lake sturgeon collected during the PSPAP also were found near the confluence with the Osage River and nearly all were hatchery-stocked fish with coded wire tags (Herman et al. 2014; Herman and Wrasse 2015, 2016).

Near-field spatial variation was evaluated using the data from the 2017-2018 biological monitoring program that encompassed an area from approximately 4.5 miles upstream to 7.5 miles downstream of the LEC discharge canal. The total number of fish collected (all gears and both study years combined) from the Upstream Reference, Thermally Exposed, and Downstream zones (Figure 4-2) were similar, at 9,150, 7,104, and 8,063 fish respectively (Table 4-10). The Discharge zone was sampled only with electrofishing gear, which produced a total of 948 fish collected. Dominant fish species were also similar across zones, with red shiner being ranked first in all zones. For numerical dominance, red shiner and gizzard shad were in the top five in abundance in all four zones, and emerald shiner and channel shiner in three zones (Table 4-10).

The make-up of the fish community was also similar between the Upstream Reference, Thermally Exposed, and Downstream zones (ASA 2019). The 2017-2018 biological monitoring study classified fish as forage, rough, game, pan, and special (ASA 2019). Numerically, all zones except the Discharge zone were dominated by forage fish, followed similar proportions of rough and game fish (Figure 4-7). The Discharge zone had higher proportions of rough and game fish and a smaller proportion of forage fish than the other zones. Rough and game fish comprised the highest proportion of biomass in all zones though game fish biomass was greatest in the Discharge zone (Figure 4-7).

Overall, there was little near-field spatial variation observed in the abundance, diversity, and fish community composition near the LEC based on the 2017-2018 biological monitoring program.



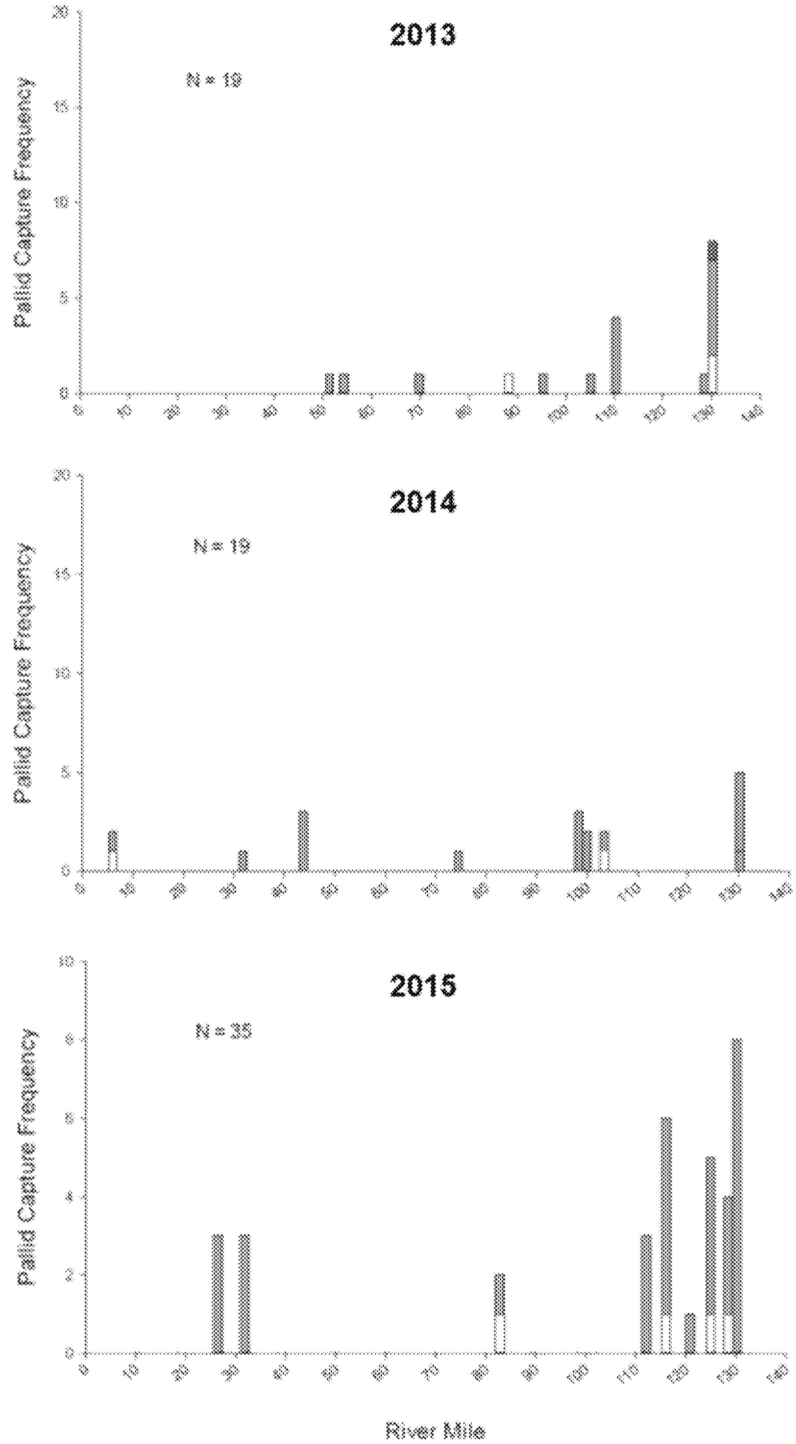
Source: Berry et al. 2004.

Figure 4-5 Number of Species Collected from River Segments Sampled During the BFS (1996-1998).

Table 4-9 Percent Difference in Abundance of Common Species in Segment 27 Relative to Segment 25 During BFS Sampling (1996-1998).

Taxon	1996	1997	1998	Total Study
Red shiner	13.2	214.8	1,126.4	427.9
Gizzard shad	239.4	345.2	130.7	236.2
Speckled (shoal) chub	50.0	351.3	-40.0	213.1
Shortnose gar	-59.4	144.7	39.1	48.4
Flathead catfish	21.7	56.3	22.4	29.7
Channel catfish	9.9	92.5	-11.6	24.6
Common carp	32.5	-7.1	50.9	15.9
Freshwater drum	39.3	21.1	-47.5	-3.6
Blue catfish	-60.3	83.3	43.6	-7.3
River carpsucker	9.1	-28.8	46.1	-23.5
Goldeye	-79.1	51.5	-40.6	-37.1
Bluegill	-48.3	-34.7	-44.1	-38.5
Emerald shiner	-95.1	-42.5	-31.1	-43.3
Unidentified silvery minnows (*Hybognathus* spp.)	-57.4	-83.4	-46.9	-74.6
All fishes	**31.1**	**22.0**	**41.7**	**29.4**

Source: Berry et al. 2004.



Source: Herman et al. 2014, Herman and Wrasse 2015, 2016

Figure 4-6 Distribution of Pallid Sturgeon Captures by RM During PSPAP Sampling (2013-2015) of Segment 14. White, Gray, and Hatched Bars Indicate Sturgeon of Wild, Hatchery, and Unknown Origins, Respectively.

Table 4-10 Species composition in each zone from fisheries sampling programs near the LEC during 2017-2018.

	Upstream Zone			Discharge Zone			Thermally Exposed Zone			Downstream Zone		
Rank	Taxon	Number	Fraction	Taxon	Number	Fraction	Taxon	Number	Fraction	Taxon	Number	Fraction
1	Red shiner	3,056	0.334	Red shiner	330	0.348	Red shiner	1,291	0.182	Red shiner	1,824	0.226
2	Channel shiner	1,287	0.141	Blue catfish	154	0.162	Emerald shiner	914	0.129	Channel shiner	1,055	0.131
3	Sicklefin chub	568	0.062	River carpsucker	67	0.071	Gizzard shad	757	0.107	Gizzard shad	980	0.122
4	Shoal chub	559	0.061	Emerald shiner	59	0.062	Channel shiner	743	0.105	Emerald shiner	636	0.079
5	Gizzard shad	557	0.061	Gizzard shad	56	0.059	Sicklefin chub	627	0.088	Shoal chub	631	0.078
6	Emerald shiner	495	0.054	Freshwater drum	46	0.049	Shoal chub	607	0.085	Sicklefin chub	472	0.059
7	Freshwater drum	487	0.053	Longnose gar	35	0.037	Freshwater drum	371	0.052	Bullhead minnow	286	0.035
8	Blue catfish	350	0.038	Shortnose gar	31	0.033	Blue catfish	282	0.040	Freshwater drum	275	0.034
9	Channel catfish	279	0.030	Flathead catfish	22	0.023	Channel catfish	242	0.034	Blue catfish	270	0.033
10	Bullhead minnow	255	0.028	Common carp	20	0.021	Silver carp	167	0.024	Channel catfish	256	0.032
11	Sand shiner	205	0.022	Channel catfish	19	0.020	Bullhead minnow	104	0.015	Silver carp	153	0.019
12	Silver carp	155	0.017	Smallmouth buffalo	19	0.020	River carpsucker	100	0.014	Goldeye	141	0.017
13	Goldeye	115	0.013	Silver carp	13	0.014	Goldeye	90	0.013	Blacktail chubs	117	0.015
14	River carpsucker	74	0.008	Striped bass x white bass	12	0.013	Longnose gar	86	0.012	Mosquitofish	105	0.013
15	Longnose gar	66	0.007	Goldeye	11	0.012	Shortnose gar	86	0.012	Sand shiner	85	0.011
>15	56 additional taxa	642	0.070	22 additional taxa	54	0.057	55 additional taxa	637	0.090	52 additional taxa	777	0.096
	Total	9,150	1.000	Total	948	1.000	Total	7,104	1.000	Total	8,063	1.000

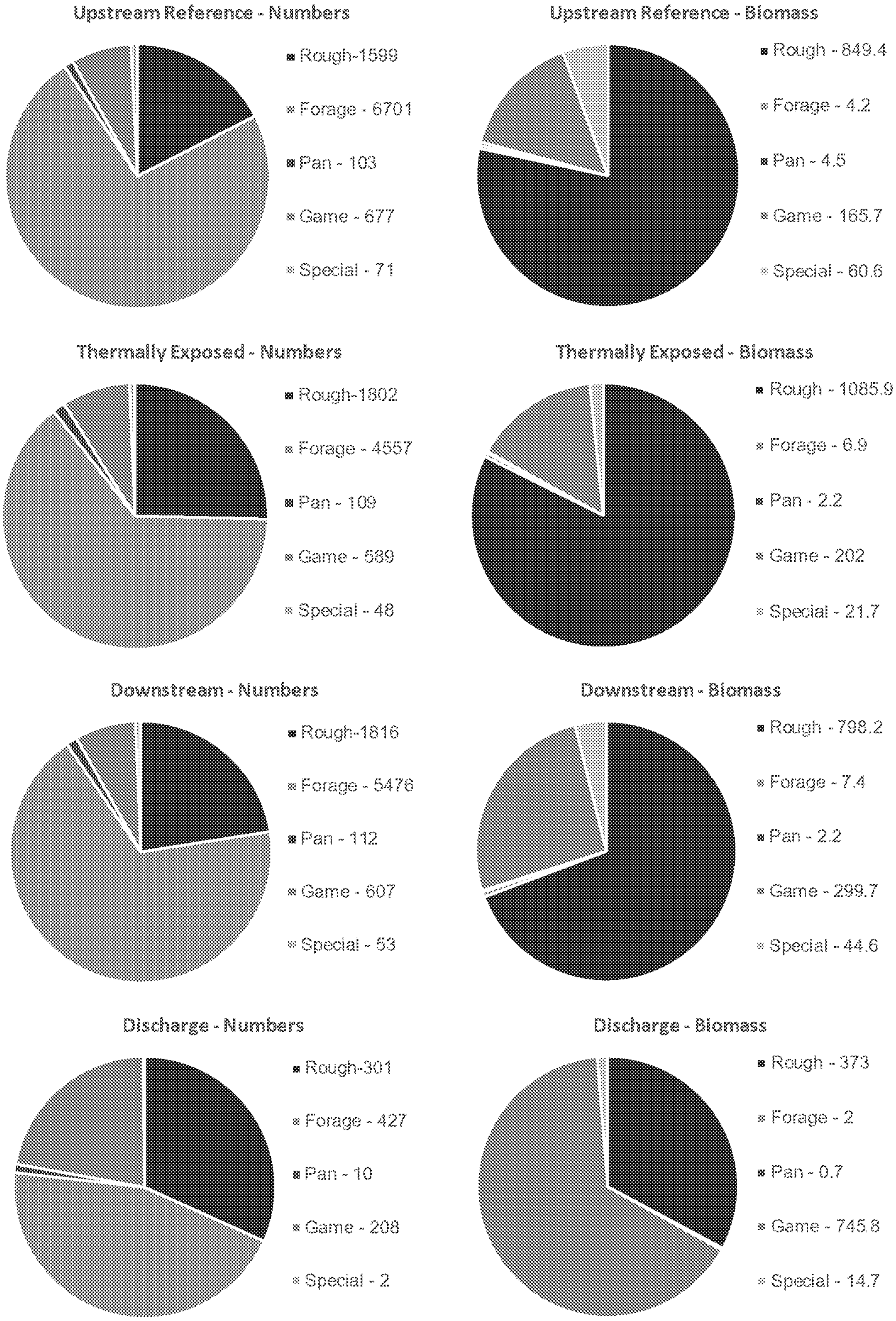


Figure 4-7 Composition of fisheries sampling results in rough, forage, pan, game, and special categories based on numerical abundance (left column) and total biomass in Kg (right) over all seasons and gear types.

4.4.2.2 Temporal Variation

The number of fish collected near the LEC during the first year of the 2017-2018 biological monitoring study tended to increase from late summer (August) and peak in fall (October) before declining over winter to levels observed throughout the rest of year (Figure 4-8). Monthly catches made during the second year of sampling were generally lower than during the first year of sampling with peak catches occurring in early spring (March and April) before declining throughout the rest of the year. These trends were observed generally in all sampling zones located in the river (1, 3, and 4) with the exception that the largest monthly catch occurred in Zone 1 in December 2017, when 2,215 red shiner were collected in a single seine sample. The temporal pattern of fish abundance within Zone 1 was nearly identical to zones 2 and 3 after excluding the one seine sample.

Monthly electrofishing catches made in the discharge canal (Zone 2) tended to be greatest during the winter and early spring months from January through March.

Periods of peak abundance for the most numerous species were determined based on monthly catches made in all sampling zones using all gears for each year of the study. During the first year of the study, species that were most abundant in early summer (June/July) included blue catfish, freshwater drum, goldeye, and longnose gar (*Lepisosteus osseus*). Bullhead minnow and gizzard shad were caught in greatest numbers during late summer (August). Many fishes were most abundant during fall months (September-November), including channel shiner, emerald shiner, shoal chub, sicklefin chub, and western mosquitofish. Two periods of high abundance of channel catfish occurred in July and September. Due to the one large seine haul of red shiner, its abundance was greatest during December, but its abundance peaked in late summer and early fall (August-September) after excluding this sample. Nearly every species was collected in greater numbers during late winter and early spring from February through April in comparison to the remaining months of the year during the second year of the study.

Patterns of impingement during 2005-2006 monitoring at the LEC (ASA and Alden 2008) resembled temporal trends observed during current monitoring of fish populations in the river as nearly 58 percent of estimated annual impingement occurred in August and September (Figure 4-9), when the 2005 year class began to be recruited to the collections. Gizzard shad and freshwater drum collectively accounted for nearly 93 percent of impingement observed during the study and approximately 52 percent of estimated impingement of gizzard shad and 77 percent of estimated impingement of freshwater drum occurred during August and September. Impingement during the period was also elevated for other species, including catfishes (blue, channel, and flathead), goldeye, and skipjack herring.

Entrainment of fish eggs (EGG), yolk-sac larvae (YSL), post yolk-sac larvae (PYSL), larvae of unknown development stage (LAR), and juvenile and adult fishes was observed from late March through late-September during the 2015 and 2016 study years (Figure 4-10). Peak entrainment took place from early to mid-June during 2015 and mid-May to early June during 2016 and was largely determined by the collection of Asian carps including silver carp and bighead carp.

Nonparametric Kruskal-Wallis rank sum tests (Kruskal and Wallis 1952) were used to determine whether entrainment densities varied among diel sampling intervals for each study year using a significance level (α) of 0.05. Independent tests were performed for each life stage after combining all taxa as well as for major taxonomic groups collected during sampling. Dunn's multiple comparison tests (Dunn 1964) were to be used to identify which diel sampling intervals differed in density. However, no significant differences in entrainment density were observed among the diel sampling intervals for any development stage during either study year when combining all taxa together (Figure 4-11, Table 4-11) or within major groups (Table 4-11).

No trend was apparent when comparing mean entrainment densities during daytime (06:00-12:00 and 12:00-18:00) and nighttime (18:00-24:00 and 00:00-06:00) sampling intervals across both study years for all taxa combined (Figure 4-12).

Reeves and Galat (2010) performed ichthyoplankton sampling at river kilometer 283 (RM 175.8) of the LMOR at four-hour increments (2:00, 6:00, 10:00, 14:00, 18:00, and 22:00) on seven dates between 30 May and 8 August 2002 to determine whether larval fishes in the LMOR exhibited a diel drift cycle. Despite mean daytime catch per unit effort (CPUE) rates of all taxa (613.52 larvae per 100 cubic meters) being 75 percent greater than mean nighttime CPUE rates (351.18 larvae per 100 cubic meters) during the study period, differences were not statistically significant. This finding supported past research (Pavlov 1994) indicating that turbid rivers lack a diel cycle of larval fish drift that is often characteristic of rivers with greater water transparency, where larval abundances tend to be greater at night.

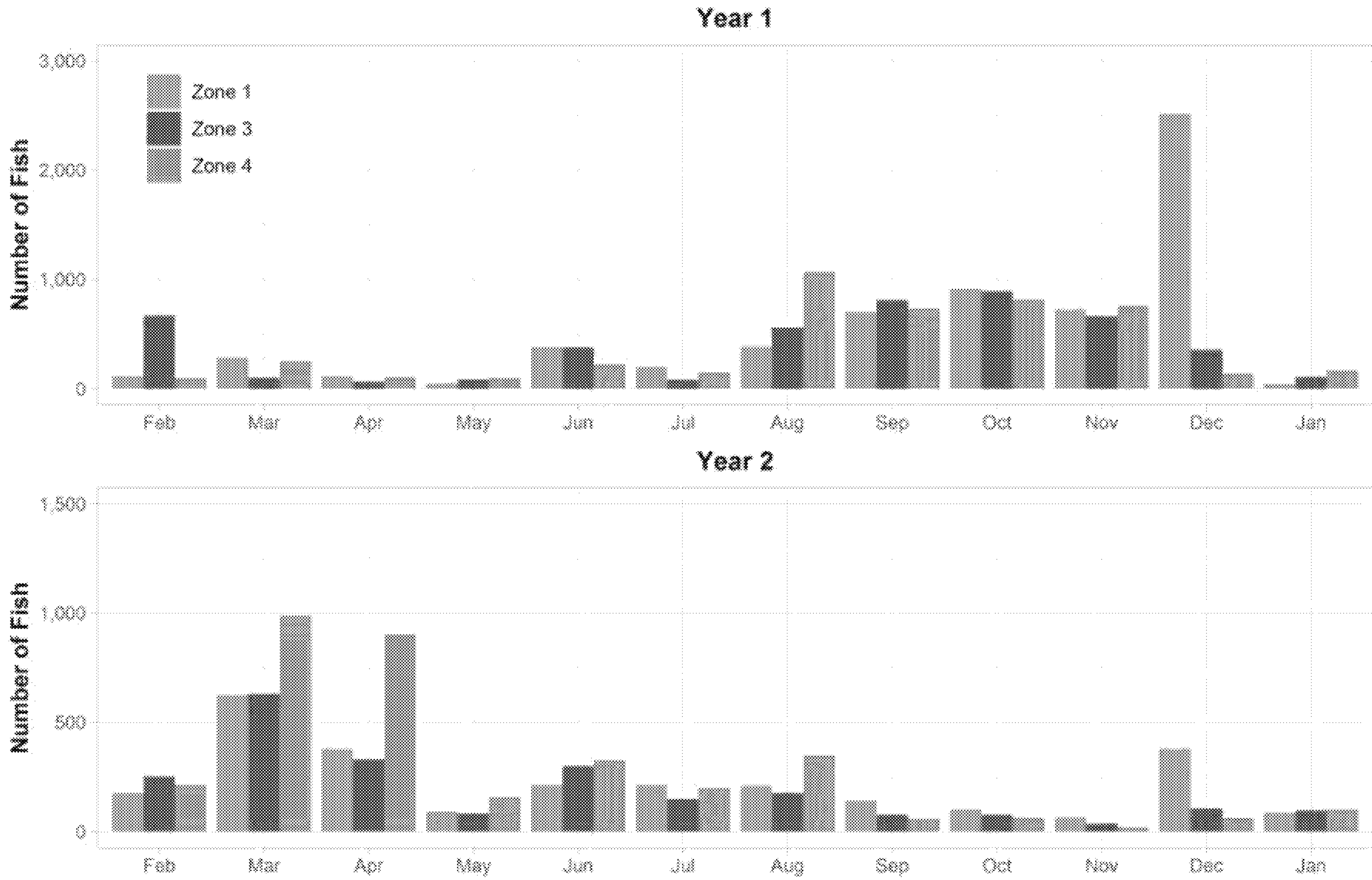
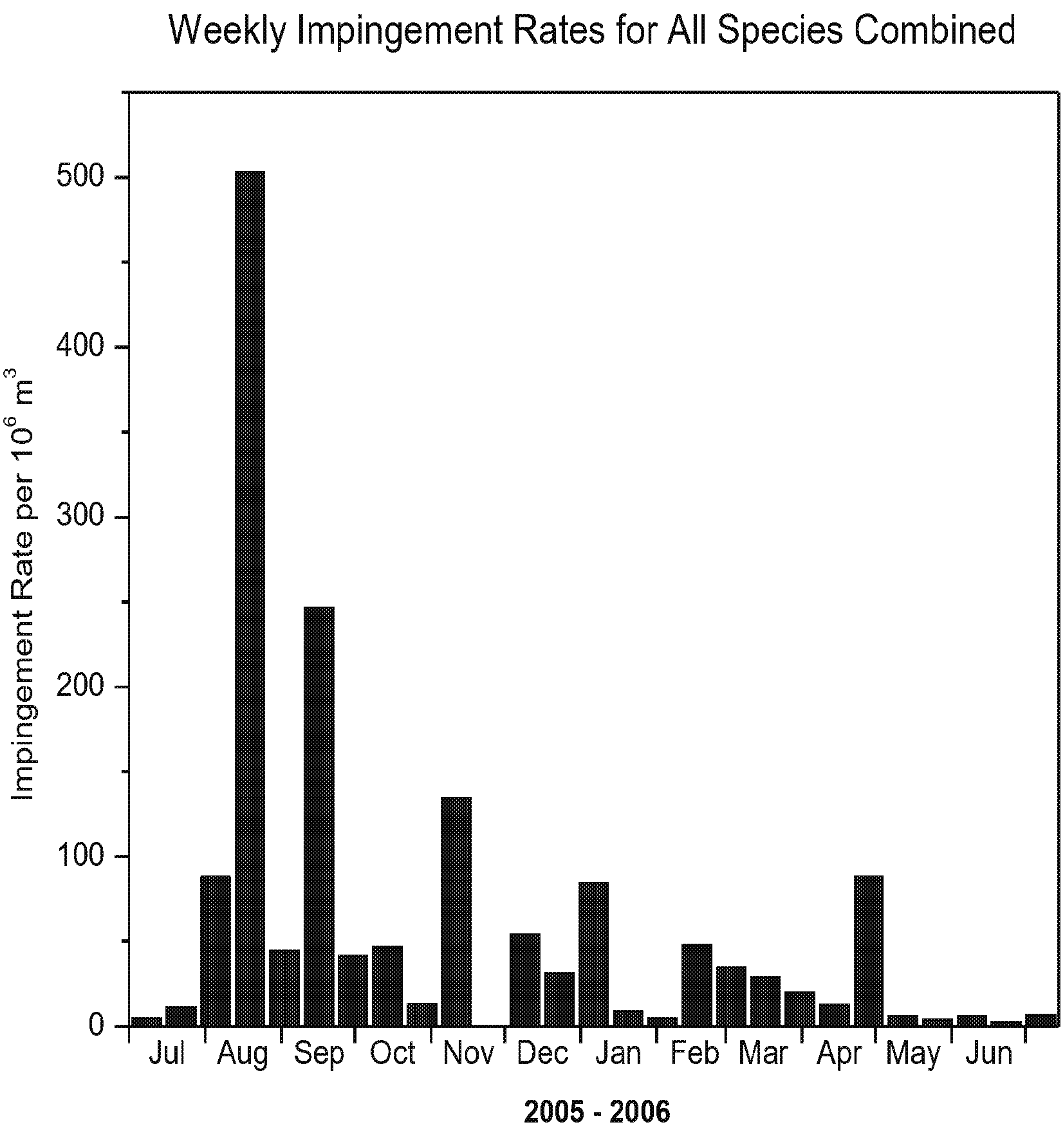


Figure 4-8 Monthly Catches of All Fishes Within Zones 1, 3, and 4 near the LEC During Each Year of the 2017-2018 Biological Monitoring Study.



Source: ASA and Alden 2008.

Figure 4-9 Weekly Impingement Rates of All Fishes During Monitoring at the LEC, 2005-2006.

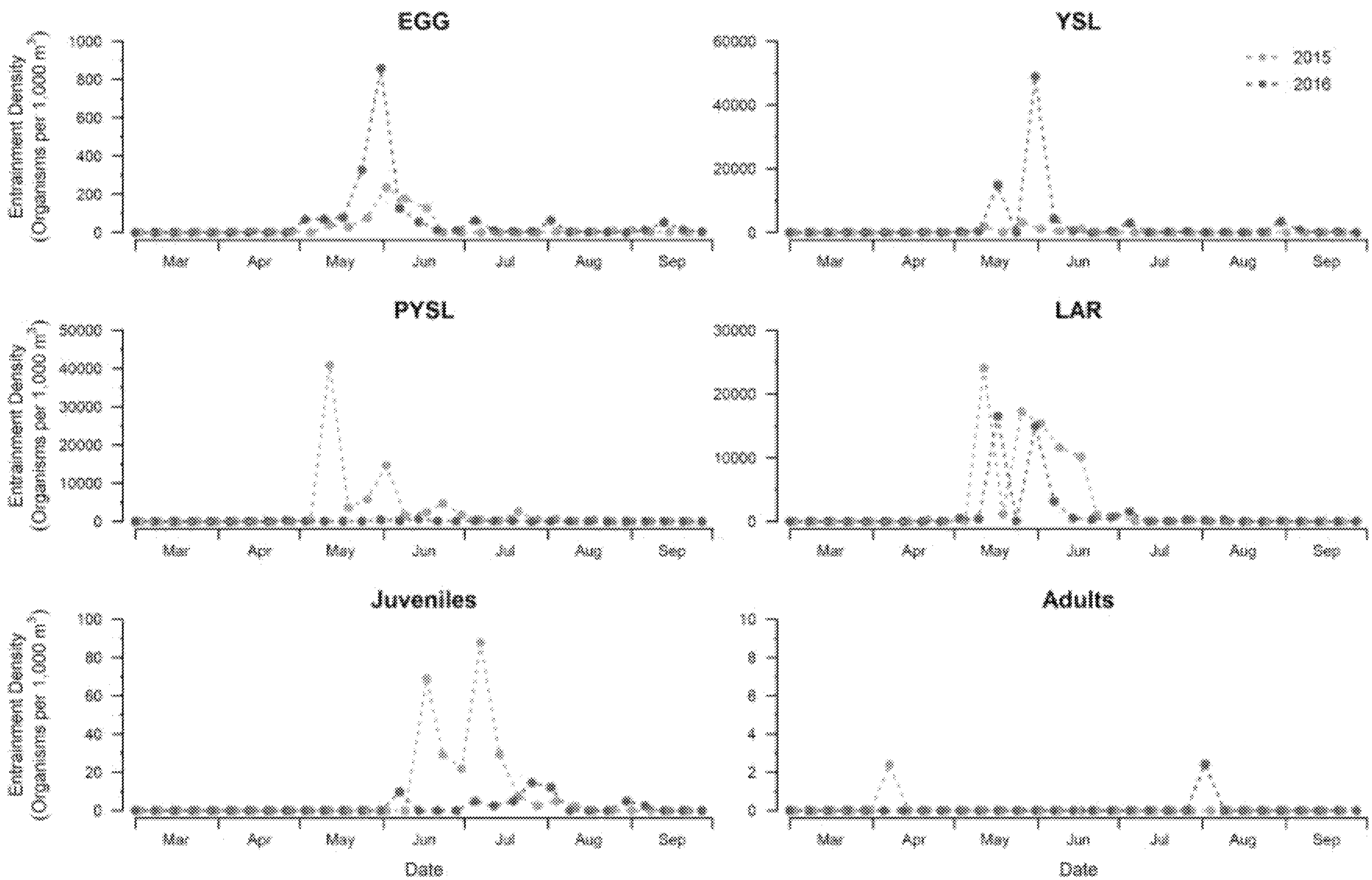


Figure 4-10 Seasonal Pattern of Entrainment of All Taxa and Life Stages During 2015 and 2016 Entrainment Characterization Sampling at the LEC.

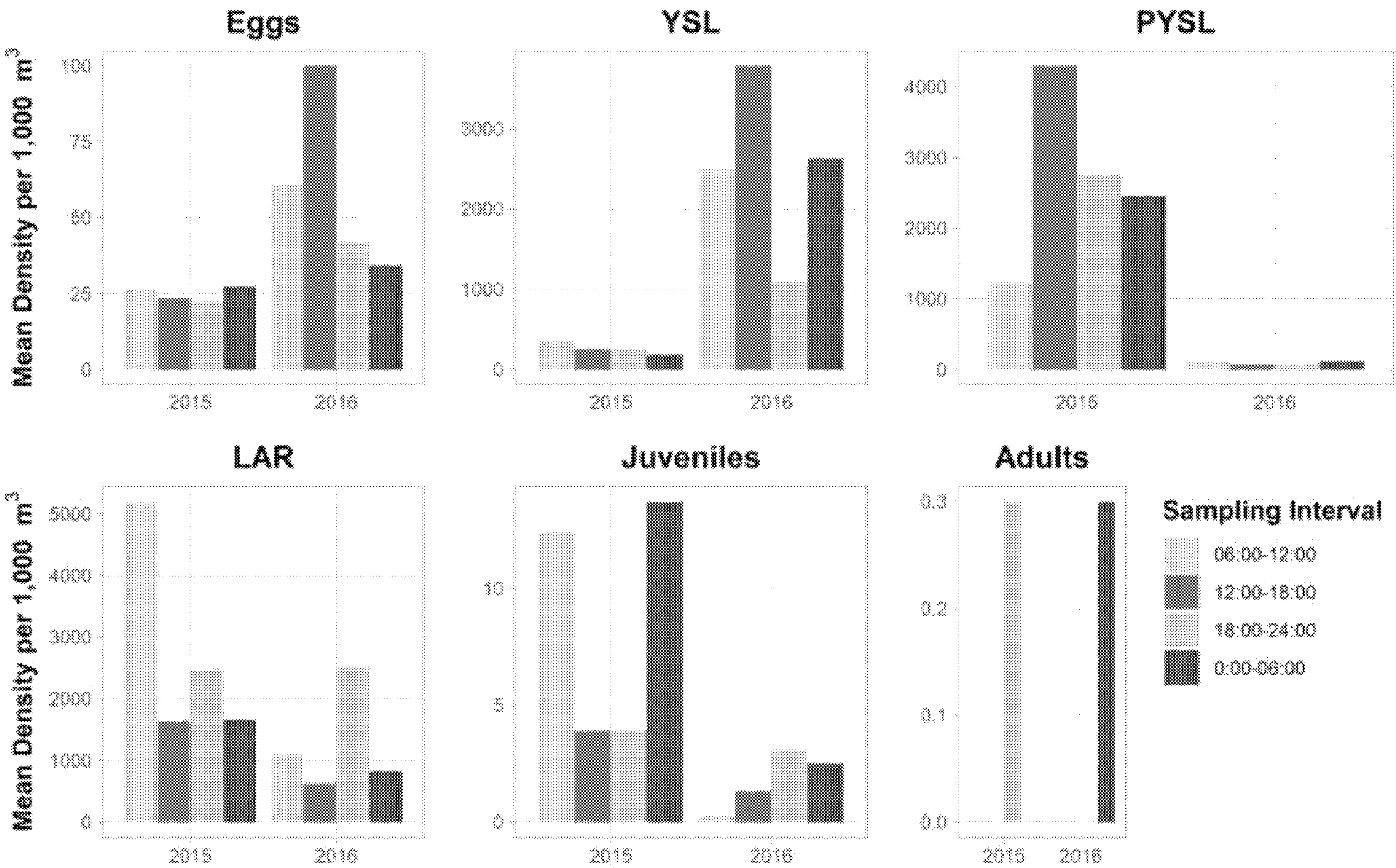


Figure 4-11 Mean Entrainment Density of All Taxa and Development Stages by Diel Periods Sampled at the LEC During 2015 and 2016.

Table 4-11 Results of Nonparametric Kruskal-Wallis Tests for Differences in Entrainment Density Among Sampling Intervals by Development Stage for Major Taxonomic Groups Collected During 2015 and 2016 Entrainment Sampling Conducted at the LEC.

Taxonomic Group	Development Stage	2015 Study Year		2016 Study Year	
		H	P-value	H	P-value
All fishes combined	Eggs	0.97	0.81	0.92	0.82
	YSL	1.12	0.77	0.15	0.99
	PYSL	0.51	0.92	0.29	0.96
	LAR	0.53	0.91	0.09	0.99
	Juveniles	0.58	0.90	4.67	0.20
	Adults	3.00	0.39	3.00	0.39
Asian carp	Eggs	--	--	3.00	0.39
	YSL	1.41	0.70	0.33	0.95
	PYSL	1.19	0.76	0.47	0.93
	LAR	1.60	0.66	1.65	0.65
	Juveniles	0.67	0.88	--	--
Carpsuckers and buffalos	YSL	5.60	0.13	0.52	0.91
	PYSL	0.23	0.97	0.21	0.98
	LAR	1.10	0.78	1.93	0.59
	Juveniles	3.00	0.39	--	--
Common carp	YSL	3.00	0.39	2.02	0.57
	PYSL	0.43	0.93	5.63	0.13
	LAR	2.02	0.57	2.02	0.57
	Juveniles	3.43	0.33	3.00	0.39
Freshwater drum	Eggs	3.96	0.27	0.99	0.80
	YSL	--	--	1.24	0.74
	PYSL	1.32	0.72	0.03	1.00
	LAR	3.21	0.36	1.79	0.62
	Juveniles	2.02	0.57	3.00	0.39
Mooneyes	YSL	0.59	0.90	0.43	0.93
	PYSL	1.83	0.61	3.68	0.30
	LAR	3.00	0.39	0.63	0.89
	Juveniles	3.00	0.39	--	--
Other carps and minnows	YSL	3.00	0.39	2.17	0.54
	PYSL	0.83	0.84	5.89	0.12
	LAR	3.42	0.33	2.38	0.50
	Adults	3.00	0.39	--	--
Shads	PYSL	0.01	1.00	3.46	0.33
	LAR	0.96	0.81	0.35	0.95
	Juveniles	0.72	0.87	4.10	0.25
All remaining fishes	Eggs	0.97	0.81	0.48	0.92
	YSL	0.70	0.87	1.98	0.58
	PYSL	0.72	0.87	0.51	0.92
	LAR	0.29	0.96	0.45	0.93
	Juveniles	1.65	0.65	4.09	0.25
	Adults	--	--	3.00	0.39

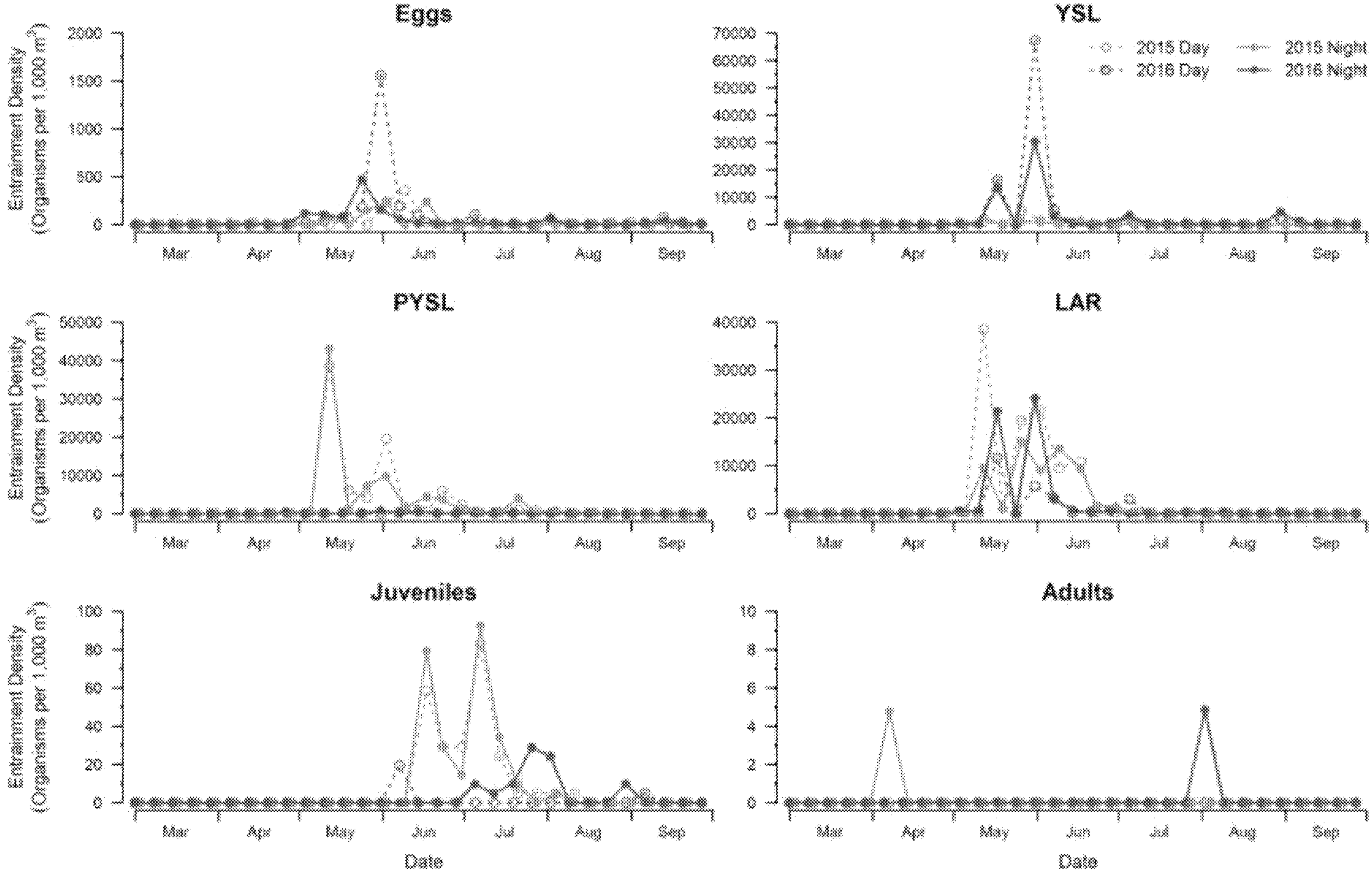


Figure 4-12 Daytime and Nighttime Entrainment Densities of All Taxa and Development Stages During 2015 and 2016 Sampling at the LEC.

4.4.3 Federal and State Protected Species

Information about the status of fish species federally or state-listed as endangered, threatened, or of special concern known to occur in the LMOR in the vicinity of the LEC is provided herein.

4.4.3.1 Pallid Sturgeon

The pallid sturgeon is a federally-listed and state-listed endangered species which occurs in the LMOR and is currently the subject of intense research and management efforts (Grady et al. 2001, USACE 2006, USGS 2005, Laustrup et al. 2007, Braaten et al. 2008, Bryan et al. 2010, Ridenour et al. 2011). There is no designated critical habitat within the LMOR (see Table 2 in USFWS 2014a). Pallid sturgeon was not found in the LMOR below RM 221 during the BFS (Berry et al. 2004) and a recent assessment of population trends using PSPAP data found no evidence for increasing relative abundance in the LMOR despite stocking efforts (Wildhaber et al. 2016). Furthermore, catch rates of pallid sturgeon have been consistently low in the most downstream reaches of the LMOR near the LEC during the PSPAP (Herman et al. 2014; Herman and Wrasse 2015, 2016). Pallid sturgeon has never been identified in samples collected near the LEC or at the facility's CWIS or in the discharge canal as part of impingement or entrainment monitoring.

The pallid sturgeon is a long-lived species and adults can reach lengths of over 6 feet, weigh up to 80 pounds, and live for up to 60 years (USFWS 2007). They are adapted to live near the bottom of large, free-flowing rivers in turbid waters and prefer a diversity of water depths and velocities such as are typically found in braided channels and around islands and sand bars and flats (USFWS 2007, 2014b). In the LMOR, pallid sturgeon primarily have been observed in channel border habitats associated with engineered structures but have also been documented in side channels with flowing water (USFWS 2014b).

Information on pallid sturgeon reproduction is scarce, though there are current efforts aimed at improving the understanding of pallid sturgeon reproductive biology and spawning behavior. Age at sexual maturity appears to be related to temperature exposure conditions as wild females have been estimated to reach maturity between 15 to 20 years while hatchery-reared females can reach maturity in as few as 6 years when exposed to constant, moderate water temperatures (USFWS 2014b). Wild male pallid sturgeon are estimated to reach sexual maturity at approximately 5 years, but similar to females, water temperatures can influence the time to sexual maturity (USFWS 2014b). Steffenson (2012) reported the minimum age-at-maturity for known aged hatchery-raised fish was age-9 for females and age-7 for males. Female pallid sturgeon do not spawn every year. In the northern part of their range, wild female pallid sturgeon spawn approximately every two to three years (Fuller et al. 2007, USFWS 2014b).

Pallid sturgeon spawning in the LMOR appears to be associated with photoperiod, water temperature, and flow and generally occurs from the end of April through May (DeLonay et al. 2012). Over their whole range, spawning has been observed from March to July with fish in the northern part of the range spawning later than those in the southern part (USFWS 2014b). While increasingly more information is becoming available on pallid sturgeon spawning habitat preferences, the relative spawning success remains unknown. DeLonay et al. (2012) demonstrated that during the upstream spawning migration, pallid sturgeon preferred the slower currents of the inside channel bends. However, spawning was shown to occur on outside channel bends in areas of deeper, swifter water over a variety of substrates and conditions.

Newly hatched larvae are attracted to light and migrate up in the water column towards the surface to enter the current. They remain pelagic and may drift downstream for up to 13 days and several hundred kilometers (km) depending on river flow and growth rates (Braaten et al. 2012; USFWS 2014b). Unlike other sturgeon species, pallid sturgeon larvae appear to drift both day and night (Braaten et al. 2012). Braaten et al. (2010) showed that freely drifting pallid sturgeon larvae were most closely associated with bottom 0.5 meters of the water column. In addition, drifting larval distribution was greatest in mid-channel and outside bend habitat locations where currents were highest. Larval sturgeon transition from free drifting to settling into benthic habitats when the larvae reach approximately 18 to 20 millimeters in length (Braaten et al. 2010).

Little is known regarding habitat preferences for settled larval and young pallid sturgeon, however they are surmised to be similar to those for the closely related shovelnose sturgeon larval and young habitat preferences (USFWS 2014b). Based on this premise, larval pallid sturgeon would prefer side-channel, low velocity habitats whereas young pallid sturgeon would show a preference for channel border habitats with moderate velocity flows (USFWS 2014b). Juvenile and adult pallid sturgeon prefer habitats with flowing water such as main channel, channel border, and secondary channel habitats (USFWS 2014b).

Early pallid sturgeon life stages appear to favor zooplankton and smaller aquatic invertebrates as a food source (USFWS 2014b). While both invertebrates and fish are important components of the pallid sturgeon diet, fish become an increasingly larger component of the diet as the pallid sturgeon grows. Gerrity et al. (2006) found that the diet of juvenile (age 6 to 7 years) shovelnose and pallid sturgeon to consist of both invertebrates and fish. Fish, mainly sicklefin chub and sturgeon chub, comprised just over 50 percent of the juvenile pallid sturgeon stomach contents while invertebrates were the dominant food source (over 70 percent) for shovelnose sturgeon.

The pre-1900 range and abundance of the pallid sturgeon is not well-known since the pallid sturgeon was only first recognized as a distinct species from the shovelnose sturgeon in 1905. The pallid sturgeon is considered endemic to Mississippi River, the Missouri River, and the lower reaches of the Yellowstone, Platte, and Kansas rivers (Dryer and Sandval 1993; USFWS 2014b). Pallid sturgeon was, therefore, adapted to the pre-development habitats in the historical Missouri and Mississippi Rivers characterized by turbid, swiftly flowing waters and a diversity of available dynamic habitats (Dryer and Sandval 1993).

The modification of the Missouri and Mississippi rivers through dam construction and channelization has resulted in changes in river flow, reduced habitat diversity, impediments to free movement within the river, and isolated subpopulations of pallid sturgeon (USNRC 2014). The conversion of the Missouri River from a turbid river with a diversity of features, depths, and velocities to a more channelized river with little variation in habitat types resulted in a loss of the preferred habitat of the pallid sturgeon and is the primary reason for the decline of the species (USFWS 2007). The pallid sturgeon was listed as endangered on 6 September 1990 (USFWS 2007, Dryer and Sandval 1993). The pallid sturgeon's current range is fragmented by mainstem dams on the Missouri River and its presence is considered scarce throughout much of its former range (USFWS 2007).

Poor recruitment of pallid sturgeon has been attributed to the loss of habitat associated with river modifications with particular focus placed on the effects of altered flows downstream of dams. However, recent research also implicates upriver effects of impoundments as reduced currents and increased microbial respiration mediated by high concentrations of fine particulate matter create anoxic transition zones that likely lead to mortality of drifting pallid sturgeon larvae (Guy et al. 2015). Observations have provided evidence of limited recruitment in the LMOR and Mississippi River. Three confirmed larval pallid sturgeon were collected in 2000 from a side channel (Lisbon Chute) at RM 217 (USNRC 2014), approximately 160 miles upstream of the LEC.

Two naturally-reproduced larval pallid sturgeon were captured in 2014 by the MDC near St. Louis and their identification was confirmed by DNA analysis (Crosby 2015). More recently, additional collections of a small number of wild-spawned pallid sturgeon larvae and suspected wild juvenile pallid sturgeon from the LMOR have been confirmed (Jacobson et al. 2016). Regardless of these observations, the population is considered neither stable nor self-sustaining (Steffenson 2012, USFWS 2014b) and it primarily consists of older individuals.

The USFWS Revised Recovery Plan for the Pallid Sturgeon (USFWS 2014b) identifies five categories of factors that may affect the status of the pallid sturgeon and its recovery:

1. Destruction, modification, curtailment of habitat and range
    - Includes river stabilization, channelization, changes in natural river hydrograph, water quality, climate change, impingement and entrainment
2. Overutilization for commercial, educational, recreational, or scientific purposes
    - Not currently a significant threat due to State and Federal regulations, but absence of regulations contributed to the decline and continued protection will be needed as the species recovers
3. Disease and predation
    - Changes in available habitats and water clarity increase vulnerability to predation
    - Increases in predatory non-native species threaten early life stages
    - Stocking of native species can have substantial impact on early life stages as well
4. Inadequate existing regulatory mechanisms
    - Lack of information on habitat preferences, population size, and sensitivity to environmental conditions and contaminants makes it difficult to assess whether existing regulations are sufficiently protective
5. Other natural and manmade factors
    - Development, hybridization, invasive/nuisance species

Missouri River recovery efforts include habitat restoration (e.g., side channels, connectivity to backwaters, dike notching), stocking through the Pallid Sturgeon Conservation Augmentation Program (PSCAP), and basin-wide population monitoring (USFWS 2007, 2014b).

There currently are four primary pallid sturgeon recovery management areas identified for the Missouri and Mississippi Rivers and their tributaries (USFWS 2014b):

- Great Plains
- Central lowlands
- Interior highlands
- Coastal plain

The area of the LMOR where the LEC is located is part of the interior highlands management area, which extends from the Fort Randall Dam downstream to the confluence with the Mississippi River.

In the LMOR, downstream of Gavins Point Dam, the release of hatchery-reared sturgeon was begun in 1994 as part of the PSCAP and has been conducted annually since 2002 (USFWS 2014b). In this same reach, ongoing habitat restoration efforts by the USACE and USFWS had created approximately 3,000 additional acres of shallow water habitat. Habitat restoration projects include the construction of chutes and side-channels and dredging to connect back-water areas (USFWS 2014b). An important consideration in the habitat restoration efforts is that because habitats in the Missouri River have been substantially altered over time, the current use of various habitats by pallid sturgeon likely reflects the use of suitable habitat instead of preferred habitat (USFWS 2014b).

4.4.3.2 Other River Sturgeons

In 2010, shovelnose sturgeon in the Missouri River became listed as a threatened species by the USFWS due to similarity of appearance to the endangered pallid (USFWS 2010). The listing, directed exclusively toward commercial fishing, extended ESA take provisions to shovelnose sturgeon, shovelnose-pallid hybrids, and their roe. Accidental or incidental capture of pallid or shovelnose sturgeon (or their hybrids) in commercial fishing gear is not considered take if sturgeons are released immediately to the wild at the point of capture and with roe intact. The shovelnose sturgeon continues to be fished recreationally within the Missouri River.

The lake sturgeon is an endangered species in the state of Missouri, and it is considered to be the rarest of the three native sturgeon species (Carlson and Pflieger 1981). Native to the Mississippi and Missouri rivers, the lake sturgeon was classified as endangered in Missouri as early as 1974 (MDC 2007). Beginning in 1984, Missouri has led an effort to annually stock (if possible) fingerling lake sturgeon into Missouri waters. A recovery plan for lake sturgeon in Missouri was initiated in 1992 and has been updated to continue annual stocking through 2016 and to study its abundance, survival, growth, and habitat with the ultimate objective of establishing a sport fishery (MDC 2007). Since 1992, lake sturgeon fingerlings have been stocked at five locations in the LMOR, three of which are below the confluence of the Gasconade River, from Hermann to Washington, Missouri. Likely as a result of the stocking program, the MDC reported the first confirmation of natural spawning of lake sturgeon in the Mississippi River near West Alton, Missouri in the spring of 2015 (Zarlenga 2015).

4.4.3.3 Minnows

Flathead chub is a state-listed endangered species in Missouri. It is highly adapted to large free-flowing rivers with swift currents and high turbidity, such as the Missouri River and Middle and Lower Mississippi River. This species experienced a dramatic decline in abundance in recent years in the Missouri River, probably as a result of the changing river hydrograph, decreased turbidity resulting from the construction of dams and reservoirs, and possible inter-specific competition with the emerald shiner, a sight feeder (Grady and Milligan 1998). Flathead chub is much more common in the less disturbed upper Missouri River, such as the reaches found in Montana (Berry et al. 2004).

The sturgeon chub is a species of special concern in Missouri with an S3 ranking according to the MONHP ranking system. It is highly adapted to large free-flowing rivers with swift currents and high turbidity. In April 2001, the USFWS found that the sturgeon chub does not warrant listing as being endangered or threatened because a stable, self-sustaining population remains widely distributed throughout its natural range, including the LMOR (USFWS 2001). Grady and Milligan (1998) did not find a significant change in the abundance of sturgeon chub in the Missouri River over the period from 1945 to 1997. Densities within the river have been found to be greatest in the segment that included the LEC between St. Joseph and St. Louis, Missouri (Grady and Milligan 1998). Seventy-eight sturgeon chub were collected during 2017-2018 monitoring surveys conducted near the LEC (ASA 2019).

Other species of special concern according to the MONHP ranking system include fishes with an S2 ranking in the minnow family that prefer quieter, backwater areas of the river, with slower velocities and with or without high turbidity. These species are the western silvery minnow, plains minnow, and ghost shiner. The western silvery minnow has shown a significant decline in abundance from 1945 to 1997, particularly at the downriver sites nearer the LEC (Grady and Milligan 1998). The plains minnow and ghost minnow also have shown declines in abundance likely related to the loss of backwater habitats in the river. The plains minnow and ghost minnow were collected during 2017-2018 monitoring surveys conducted near the LEC (ASA 2019).

4.4.3.4 Other Fishes

Highfin carpsucker (S2) and river darter (S3) are species of special concern according to the MONHP ranking system that have been collected in low numbers from segments of the river near the LEC (Berry et al. 2004, Herman et al. 2014, Herman and Wrasse 2015, 2016). Both species inhabit small to large rivers with the highfin carpsucker found in pools and backwaters (Fishbase 2018a) and the river darter in rocky riffles (Fishbase 2018b). Neither species has been collected during sampling conducted at the LEC.

4.4.4 Summary of Fish Community Composition

The Missouri River has changed dramatically over the past century due to human modifications intended to manage the river for navigation and flood control, which began in the late 1800s with removal of snags to permit navigation (NRC 2002). Channel enhancements began in the early 1900s and damming and flow regulation began in the 1930s. The river modifications culminated in the construction of five USACE dams on the upper mainstem of the river in the 1950s and 1960s and the completion of the Missouri River Bank Stabilization and Navigation Project in the lower, unimpounded river in 1981. These modifications have reduced or eliminated the river's natural flow regime in which flood pulses in the spring and early summer would create new and productive habitats, cycle organic material and nutrients between the channel and floodplain, replenish water, and serve as cues for spawning of fish and other organisms. As a result, the amount of productive, natural habitat has been greatly reduced. To mitigate the loss of riverine habitat and the natural flow regime, the USACE has instituted the MRRP.

The LEC is located on the south bank in the channelized reach of the LMOR, where the river has also been substantially altered by the construction of revetments and dikes and by dredging to maintain a 300-ft wide and 9-ft deep navigation channel. As a result, the channel now is narrower and more uniform than its previous form, with a trapezoidal cross-section resulting in steeper embankments and faster currents. River meanders have been straightened, natural riparian vegetation has been lost, variations in river flows and water temperatures are reduced, periodic overbank flow to the floodplains and its nutrient cycling benefits have been eliminated or reduced, sediment transport is reduced, and natural processes of cut and fill alleviation have been modified.

The modifications and loss of the natural riverine flow regime and habitats has greatly influenced the abundance of native species and affected the overall composition of the fish community. Present river conditions favor sight feeders (e.g., skipjack herring, white bass, mimic shiner, and spotfin shiner) that have adapted to lower turbidity levels over native species (Berry and Young 2001). Many native fish species are now rare, uncommon, or decreasing in abundance across part or all of their previous range (NRC 2002). Berry and Young (2001) estimated that approximately 35 native species are declining in abundance while 23 species are increasing. Some of the native species most affected include the pallid sturgeon, plains minnow, sauger, sturgeon chub, and sicklefin chub (NRC 2002).

In many river reaches, the abundance of non-native species has become greater than that of native species because of their greater tolerance for the altered temperature regime, flow, turbidity, and habitats. Species of Asian carp, including bighead, silver, and grass carp, are among the most notable nonnative species now present in the LMOR. Introduced to the United States by natural resource agencies and aquaculturists in 1970s as intended biological tools, Asian carps subsequently have spread throughout the Mississippi River basin. Due to their wide tolerance of environmental conditions and life history characteristics, including rapid growth, early maturation, high fecundity, and protracted spawning, these species have been highly successful in establishing populations in numerous river systems (Wanner and Klumb 2009, Sullivan 2016). Given their ability to alter water quality and obtain high densities (Freedman et al. 2012), Asian carp have the potential to cause ecological harm to native fishes and other aquatic organisms as they expand throughout the Missouri River.

There were 105 species and three hybrids collected during fish surveys conducted within segments of the LMOR near the LEC (Table 4-12), including studies conducted at the facility. More than half of all taxa belonged to the carp and minnow (37 species), sucker (14 species), and sunfish (12 species) families. Based on their presence during all population surveys, 32 species were relatively common within the LMOR. Conversely, another 31 taxa (29 species, 2 hybrids) were found only once during either sampling within the river or impingement monitoring at the LEC CWIS intake, which may indicate that they were rare visitors, occupied a narrow geographic range within this section of the river, or were not readily sampled by the methods used.

Two federal-listed species were collected, including the endangered pallid sturgeon (USFWS 2015) and the threatened shovelnose sturgeon (USFWS 2010). There is no designated critical habitat within the LMOR for pallid sturgeon (Table 2 in USFWS 2014a), which is also a Missouri-listed endangered (S1 MONHP ranking) species. It was only collected during the PSPAP, which was designed to estimate the population size, structure, and distribution of the species. The majority were collected upstream of RM 100 with the highest concentrations located near confluences with the Osage River at RM 130.2 and the Gasconade River at RM 105. No pallid sturgeon were definitively identified during collections made in the vicinity of the LEC or at the CWIS intake. One possible pallid sturgeon specimen was collected during the 2017-2018 biological monitoring program but could not be definitively identified. As a result, the identification of this specimen remained as an unidentified river sturgeon (*Scaphirhynchus* sp.). Shovelnose sturgeon are numerous in the LMOR and the species continues to be fished recreationally. Three Missouri state-listed endangered lake sturgeon were collected near the LEC during the 2017-2018 biological monitoring study.

Additional Missouri state-listed endangered (S1) species found during sampling included lake sturgeon and flathead chub. Neither was caught in abundance within the LMOR and most lake sturgeon collected during the PSPAP were hatchery-stocked fish found more than 70 miles upstream of the LEC near the confluence with the Osage River. Additional species of state concern according to the MONHP ranking system were four species assigned an S2 ranking, ghost shiner, highfin carpsucker, plains minnow, and western silvery minnow; two species assigned an S3 ranking, river darter and sturgeon chub; and two species assigned an SU ranking, skipjack herring and American eel. Only sturgeon chub was found in abundance, when 222 were caught during 2013-2015 PSPAP sampling in Segment 14. A total of 78 sturgeon chubs and 3 ghost shiners were caught during the biological monitoring conducted near the LEC during 2017-2018 biological monitoring.

Differences in sampling gears employed during fish population surveys conducted within the LMOR near the LEC yielded inconsistent relative abundances and ranked orders of abundance of taxa. However, nine fishes were frequently listed among the 15 most numerous taxa collected during nearly all surveys. These species included three catfishes (blue, channel, and flathead), freshwater drum, gizzard shad, goldeye, longnose gar, red shiner, and river carpsucker. These fishes accounted for between 61 and 78 percent of all fishes collected during historical and current sampling efforts at the LEC and the BFS program as well as 57 percent of those collected during the PSPAP after excluding shovelnose sturgeon, which was particularly abundant due to a sampling design that targeted the endangered pallid sturgeon.

Notably, Asian carp species were not among the most numerous taxa collected as juveniles or adults during the sampling programs conducted in the LMOR near the LEC. A number of traditional sampling gears have been demonstrated to be ineffective at sampling Asian carps, including bag seines, set lines, trot lines, beam trawls, and otter trawls. Instead, hoop nets, mini-fyke nets, push trawls, experimental gill nets, and trammel nets have been shown to be most effective with the sampling efficiency of each individual gear varying considerably among bighead, silver, and grass carp (Wanner and Klumb 2009). The PSPAP employed three of these gears (gill nets, mini-fyke nets, and trammel nets), which may account for the high catch of silver carp (n=346) between 2013 and 2015 by that program in comparison to the other sampling efforts reviewed. The dominance of Asian carp larvae in ichthyoplankton samples collected from the LMOR (Reeves and Galat 2010), including during 2017-2018 biological monitoring near the LEC and entrainment sampling conducted in the LEC discharge during 2015 and 2016, indicate that these species are established and reproducing near the facility.

The LMOR provides good fishing opportunities for trophy catfish (McKinstry 2016) and blue, channel, and flathead catfishes were among the most commonly collected species during population surveys. Other recreational fishes sought in the LMOR include freshwater drum, white bass, hybrid striped bass (*Morone saxatilis*) × white bass, and shovelnose sturgeon (MDC 2017) and other game and panfish. Commercial fishing has been conducted within the Missouri portion of the river for decades. The number of issued permits and total harvests have declined during recent years and fishes that were once commonly targeted are now protected from commercial fishing, including catfishes, paddlefish, and shovelnose sturgeon (MCSR 2018). A number of taxa sustain the commercial fishery as buffalos (bigmouth, smallmouth, and black), common carp, and Asian carps (bighead and silver) currently comprise the majority of fish harvested (Tripp et al. 2012).

A number of species were present in the BFS segment most proximate to the LEC (Segment 27) at elevated densities in comparison to the most proximate upstream segment (Segment 25), including red shiner, gizzard shad, speckled (shoal) chub, and shortnose gar. In contrast, goldeye, bluegill, emerald shiner, and silvery minnows were more abundant upstream and catfishes (blue, channel, and flathead), common carp, and freshwater drum were relatively evenly distributed between the segments.

Monthly catches made near the LEC during the first year of the 2017-2018 biological monitoring study increased from August until peaking in October before declining over winter to levels observed throughout the rest of year. However, monthly catches peaked in early spring during the second year of sampling, when catches were generally lower than during the first year. Rates of impingement were greatest during late summer and fall during 2005-2006 monitoring, when the majority of impingement was dominated by gizzard shad and freshwater drum. Peak densities observed during these periods likely represent the recruitment of new age classes.

Table 4-12 Fish Taxa Identified by Studies within the LMOR and in the Immediate Vicinity of the LEC, 1974-2018.

Family	Scientific Name	Common Name	LMOR Surveys		LEC Site Surveys		LEC Impingement	
			BFS Segments 25 & 27	PSPAP Segment 19	Past	2017-2018	1974-1975	2005-2006
Acipenseridae-sturgeons	*Acipenser fulvescens*	Lake sturgeon	X	X		X		X
	Scaphirhynchus albus	Pallid sturgeon		X				
	Scaphirhynchus platorynchus	Shovelnose sturgeon	X	X	X	X		X
	S. albus × S. platorynchus	Pallid sturgeon × shovelnose sturgeon		X				
Amiidae-bowfins	*Amia calva*	Bowfin	X					
Anguillidae-freshwater eels	*Anguilla rostrata*	American eel		X	X			
Atherinopsidae-New World silversides	*Labidesthes sicculus*	Brook silverside	X	X	X	X		
Catostomidae-suckers	*Carpiodes carpio*	River carpsucker	X	X	X	X	X	X
	Carpiodes cyprinus	Quillback	X	X	X	X		X
	Carpiodes velifer	Highfin carpsucker	X	X				
	Catostomus commersonii	White sucker		X	X			
	Cycleptus elongatus	Blue sucker	X	X	X	X		X
	Hypentelium nigricans	Northern hog sucker		X				
	Ictiobus bubalus	Smallmouth buffalo	X	X	X	X		
	Ictiobus cyprinellus	Bigmouth buffalo	X	X	X	X		
	Ictiobus niger	Black buffalo		X	X	X		
	Minytrema melanops	Spotted sucker				X		
	Moxostoma anisurum	Silver redhorse				X		
	Moxostoma carinatum	River redhorse		X				
	Moxostoma erythrurum	Golden redhorse		X	X	X		X
	Moxostoma macrolepidotum	Shorthead redhorse	X	X	X	X	X	X
Centrarchidae-sunfishes	*Ambloplites rupestris*	Rock bass			X		X	X

Family	Scientific Name	Common Name	LMOR Surveys		LEC Site Surveys		LEC Impingement	
			BFS Segments 25 & 27	PSPAP Segment 19	Past	2017-2018	1974-1975	2005-2006
	Lepomis cyanellus	Green sunfish	X	X	X	X		X
	Lepomis gulosus	Warmouth		X				X
Centrarchidae-sunfishes	*Lepomis humilis*	Orangespotted sunfish	X	X		X		
	Lepomis macrochirus	Bluegill	X	X	X	X	X	X
	Lepomis megalotis	Longear sunfish	X		X	X		
	Lepomis punctatus	Spotted sunfish		X				
	Micropterus dolomieu	Smallmouth bass			X			
	Micropterus punctulatus	Spotted bass	X		X	X		
	Micropterus salmoides	Largemouth bass	X	X	X	X		X
	Pomoxis annularis	White crappie	X	X	X	X	X	X
	Pomoxis nigromaculatus	Black crappie	X	X	X	X		
Clupeidae-herrings	*Alosa chrysochloris*	Skipjack herring	X	X	X	X		X
	Dorosoma cepedianum	Gizzard shad	X	X	X	X	X	X
Cyprinidae-carps and minnows	*Campostoma anomalum*	Central stoneroller		X		X		
	Campostoma oligolepis	Largescale stoneroller	X			X		
	Carassius auratus	Goldfish		X		X		X
	Ctenopharyngodon cf. idella	Grass carp	X	X	X	X		
	Cyprinella lutrensis	Red shiner	X	X	X	X		X
	Cyprinella spiloptera	Spotfin shiner		X				
	Cyprinus carpio	Common carp	X	X	X	X	X	X
	Erimystax x-punctatus	Gravel chub		X		X		
	Hybognathus nuchalis	Sillvery minnow				X		
	Hybognathus placitus	Plains minnow	X	X		X		
	Hypophthalmichthys molitrix	Silver carp		X	X	X		X

Family	Scientific Name	Common Name	LMOR Surveys		LEC Site Surveys		LEC Impingement	
			BFS Segments 25 & 27	PSPAP Segment 19	Past	2017-2018	1974-1975	2005-2006
	Hypophthalmichthys nobilis	Bighead carp	X	X	X	X		X
	Luxilus chrysocephalus	Striped shiner	X					
	Luxilus cornutus	Common shiner	X	X				
	Lythrurus umbratilis	Redfin shiner						X
Cyprinidae-carps and minnows	*Macrhybopsis gelida*	Sturgeon chub	X	x		X		X
	Macrhybopsis hyostoma	Shoal chub[1]	X	X		X		x
	Macrhybopsis meeki	Sicklefin chub	x	X		X		
	Macrhybopsis storeriana	Silver chub	X	X		X		
	Notemigonus crysoleucas	Golden shiner	X	X				
	Notropis atherinoides	Emerald shiner		X	X	X		X
	Notropis blennius	River shiner	X	X		X		
	Notropis boops	Bigeye shiner	X	X		X		
	Notropis buchanani	Ghost shiner	X	X		X		
	Notropis dorsalis	Bigmouth shiner	X					
	Notropis rubellus	Rosyface shiner	X			X		
	Notropis shumardi	Silverband shiner				X		
	Notropis stramineus	Sand shiner	X		X	X		
	Notropis volucellus	Mimic shiner	X	X	X		X	
	Notropis wickliffi	Channel shiner	X	X		X		
	Phenacobius mirabilis	Suckermouth minnow		X		X		
	Pimephales notatus	Bluntnose minnow	X	X		X		
	Pimephales promelas	Fathead minnow	X	X		X		
	Pimephales vigilax	Bullhead minnow	X	X		X		X
	Platygobio gracilis	Flathead chub	X	X				

Family	Scientific Name	Common Name	LMOR Surveys		LEC Site Surveys		LEC Impingement	
			BFS Segments 25 & 27	PSPAP Segment 19	Past	2017-2018	1974-1975	2005-2006
	Semotilus atromaculatus	Creek chub	X			X		
	Esox lucius	Northern pike						
Esocidae-pikes and mudminnows	*Fundulus olivaceus*	Blackspotted topminnow	X					
Fundulidae-topminnows	*Fundulus diaphanus*	Banded killifish		X		X		
	Hiodon alosoides	Goldeye			X	X		X
Hiodontidae-mooneyes	*Hiodon tergisus*	Mooneye	X	X	X	X		X
Hiodontidae-mooneyes	*Ameiurus melas*	Black bullhead		X			X	
	Ameiurus natalis	Yellow bullhead		X				
	Ictalurus furcatus	Blue catfish		X	X	X	X	X
	Ictalurus punctatus	Channel catfish	X	X	X	X	X	X
Ictaluridae-North American catfishes	*Noturus flavus*	Stonecat	X	X			X	X
	Noturus gyrinus	Tadpole madtom	X	X				
	Noturus nocturnus	Freckled madtom		X		X		X
	Pylodictis olivaris	Flathead catfish	X	X	X	X	X	X
	Lepisosteus oculatus	Spotted gar	X	X				
	Lepisosteus osseus	Longnose gar	X	X	X	X	X	
Lepisosteidae-gars	*Lepisosteus platostomus*	Shortnose gar	X	X	X	X		
	Morone chrysops	White bass	X	X	X	X	X	X
	Morone mississippiensis	Yellow bass	X	X				
Moronidae-temperate basses	*Morone saxatilis*	Striped bass	X	X	X		X	
	M. saxatilis × M. chrysops	Striped bass × white bass	X	X	X	X		
	Osmerus mordax	Rainbow smelt		X				
Osmeridae-smelts	*Etheostoma nigrum*	Johnny darter	X			X		
Percidae-perches	*Etheostoma tetrazonum*	Missouri saddled darter	X	X				

Family	Scientific Name	Common Name	LMOR Surveys		LEC Site Surveys		LEC Impingement	
			BFS Segments 25 & 27	PSPAP Segment 19	Past	2017-2018	1974-1975	2005-2006
	Etheostoma zonale	Banded darter		X				
	Percina caprodes	Logperch		X		X		
	Percina maculata	Blackside darter	X	X				
	Percina phoxocephala	Slenderhead darter		X				
	Percina shumardi	River darter		X				
	Sander canadensis	Sauger		X	X	X		X
	Sander vitreus	Walleye	X	X	X	X		
	S. canadensis × *S. vitreus*	Saugeye (Sauger × walleye)	X	X		X		
Percidae-perches	*Ichthyomyzon castaneus*	Chestnut lamprey			X	X	X	
Petromyzontidae-lampreys	*Ichthyomyzon unicuspis*	Silver lamprey	X	X		X		
	Gambusia affinis	Western mosquitofish				X		
Poeciliidae-liverbearers	*Polyodon spathula*	Paddlefish	X	X	X	X		
Polyodontidae-paddlefishes	*Aplodinotus grunniens*	Freshwater drum	X	X	X	X	X	X
Sciaenidae-drums and croakers	**68**	**83**	X	X	**18**[2]	**35**		
No. of species			**0**	**2**	**45**	**71**	**0**	**0**
			0	**2**				

[1] The shoal chub was elevated to full species status from the speckled chub species-complex through morphological studies by Eisenhour (1999, 2004) and genetic studies by Underwood et al. (2003). Henceforth, all specimens formerly identified as speckled chub are now identified as shoal chub.
[2] 20 species reported in EEHI 1976a.

4.5 SHELLFISH COMMUNITY COMPOSITION

North America has a large diversity of freshwater mussels, which are bivalve mollusks (Class Bivalvia) in the family Unionidae. Historically, the Midwestern United States provided a rich habitat for many species (USFWS 2017) and approximately 65 species are found in Missouri waters (Bruenderman et al. 2002). Over-harvesting of mussels prior to establishment of protections, impounding of streams and rivers, pollution, siltation, and introduction of invasive species, such as the zebra mussel (*Dreissena polymorpha*), were associated with declines in species richness and abundance of mussels in Midwestern waters over the last two centuries (Daubert 2013, USFWS 2017).

Freshwater mussel populations within the Missouri River were not studied extensively until recent decades. With the exception of early reports of populations of the freshwater pearl mussel (*Margaritifera margaritifera*) and fatmucket (*Lampsilis siliquoidea*) from upper reaches in Montana (Bland and Cooper 1861, Cooper 1869), much of the river, including the middle and lower sections, was considered devoid of unionids due to high silt loads that prevented their growth, reproduction, and dispersal (Bartsch 1916).

Although the Missouri River likely never provided an abundance of high quality habitat for freshwater mussels, its tributaries were known to host many species (Hayden 1862, Coker and Southall 1915) and the morphology of the river prior to dam construction and channel modifications, which included wide meanders, side channels, and backwaters, likely did provide suitable habitat (Perkins and Backlund 2000). Recent work (Hoke 1983, Perkins and Backlund 2000, Hoke 2009) has demonstrated that a number of species persist in the river despite the loss of many of these former habitats. The current assemblage is comprised of many mussels that are tolerant of high concentrations of silt, however species known to be intolerant to silt are present as well, including scaleshell (*Leptodea leptodon*) and yellow sandshell (*Lampsilis teres*).

4.5.1 Freshwater Mussel Surveys

Few studies of freshwater mussels have been conducted within the Missouri River and, particularly, within the LMOR. Hoke (1983) provided the first documentation of significant numbers of freshwater mussels in the river, when 13 species were found along the segment that determines the Nebraska border. Follow-up surveys performed by Hoke (2009) provided coverage of the channelized portion of the LMOR, including the sections of the river nearest to the LEC. An additional survey (Perkins and Backlund 2000) conducted in the uppermost section of the LMOR below Gavins Point Dam provided additional insight into mussel species that are present in the river. The 2017-2018 biological monitoring study conducted at the LEC also included qualitative sampling for shellfish conducted during 2017 and 2018 to detect the presence of any threatened or endangered species (ASA 2019). Methodology and results of these studies are presented below.

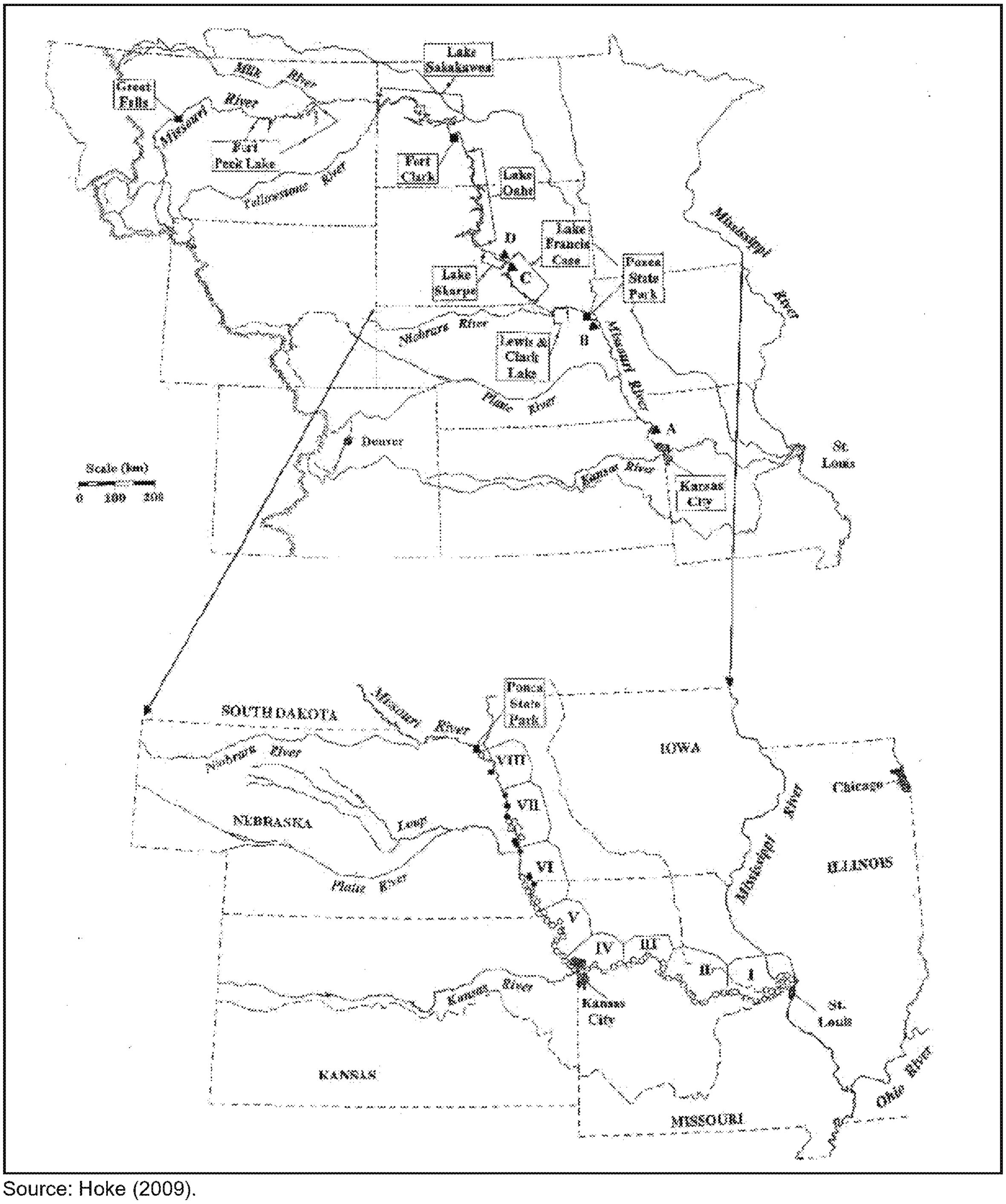
4.5.1.1 Survey of the Channelized LMOR

Hoke (2009) reported on the findings of unionid surveys conducted within eight regions of the channelized LMOR extending from the mouth of the river above St. Louis, Missouri (RM 0.0) to Ponca State Park, Nebraska (RM 750.2, Figure 4-13). Surveys were performed between 1982 and 2000 with most conducted from 1988 to 1990 during the late fall and winter months. Sites extended as far as 2 km and were selected opportunistically based upon available access to the river. Shells were sampled by hand or using a garden rake until diversity plateaued or no accessible area remained. Site habitats were identified according to the following categories: sandbars, pools below wing dams, side channels, detached lakes, sloughs, backwaters, revetments, and accessible portions of the main channel.

Fourteen total native freshwater mussel species were identified during searches conducted at 71 sites distributed across the eight collection regions (Table 4-13). The exotic Asian clam also was found at sites located in several regions. No species previously known to occur in the LMOR was absent during the survey, whereas eight species were reported for the first time. Regions I and II, which included areas of the river near the LEC, were the most species-rich regions as all 14 native species were present within one of the two regions. The diversity of habitats associated with a relatively wider river width in these regions and an abundance of sites accessible for conducting searches likely contributed to the increased richness of mussels in these regions. The most common species were pink papershell (*Potamilus ohiensis*), fragile papershell (*Leptodea fragilis*), and giant floater (*Pyganodon grandis*). Fragile papershell was found in habitats with moderate currents, whereas pink papershell and giant floater tended to be more numerous in quiet waters.

Mussels were generally absent from areas with strong currents as their distributions tended to be limited to habitats with slow to moderate currents with stable substrates that rarely experience dewatering during periods of low flow. Sites with habitats that were sheltered from strong currents frequently yielded high numbers of unionids. Pools below wing dams were the most common habitat for mussels during the study, which may account for the presence of many silt-tolerant species in the LMOR as silt is deposited in these areas. Mussels also were found in natural habitats, such as those provided by inside banks below sharp bends or in substrates of natural rock and sediment.

One recently dead specimen of the federal and state-listed endangered scaleshell, which also has an MONHP ranking of S1 (MDC 2018), was collected from Region I during the survey. Hickorynut (*Obovaria olivaria*), which has an MONHP ranking of S3 (MDC 2018), was similarly rare as a single specimen was collected from Region II. In contrast, the flat floater (*Anodonta suborbiculata*), which was an MONHP ranking of S2 (MDC 2018), was the fifth-most numerous native species collected during the survey. No other species of conservation concern was found during the study.



Source: Hoke (2009).

Figure 4-13 Freshwater Mussel Collection Regions (Roman Numerals) and Sites (Circles and Triangles) Surveyed Between 1982 and 2000 Within the Channelized LMOR.

Table 4-13 Number of Freshwater Mussels Collected During Surveys Conducted Between 1982 and 2000 Within the Channelized LMOR.

Common Name	Region								Total
	I	II	III	IV	V	VI	VII	VIII	
Flat floater	7	3	2	-	3	1	3	2	21
Yellow sandshell	1	3	-	1	2	-	1	-	8
White heelsplitter	3	-	1	-	1	-	1	1	7
Fragile papershell	8	9	4	7	6	6	4	1	45
Scaleshell	1	-	-	-	-	-	-	-	1
Threehorn wartyback	2	1	-	-	-	-	-	-	3
Hickorynut	-	1	-	-	-	-	-	-	1
Pink heelsplitter	4	6	4	3	4	1	-	1	23
Pink papershell	12	8	4	6	6	4	5	1	46
Giant floater	9	8	5	3	2	4	6	1	38
Mapleleaf	2	2	-	-	1	-	-	-	5
Lilliput	1	2	-	-	-	-	1	-	4
Fawnsfoot	1	2	-	1	-	-	-	1	5
Paper pondshell	3	1	-	-	1	-	1	-	6
Total unionids	54	46	20	21	26	16	22	8	213
Nonnative Asian clam	13	9	-	4	-	-	-	-	26
Total	67	55	20	25	26	16	22	8	239
No. of unionid species	13	12	6	6	9	5	8	7	15
No. of sites	15	10	6	8	11	9	10	2	71
No. of species per site	3.60	4.60	3.33	2.63	2.36	1.78	2.20	4.00	3.00

Source: Hoke (2009).

4.5.1.2 Gavins Point Reach Survey

Perkins and Backlund (2000) surveyed freshwater mussels within the Gavins Point Reach of the Missouri National Recreational River, which extends approximately 60 miles from Gavins Point Dam near Yankton, South Dakota (RM 810.0) to Ponca State Park, Nebraska (RM 750.2). Surveys were conducted in 1999 by traveling the study area by boat and investigating sandbars and islands for the presence of unionid shells. Sites with shells were searched further by feeling the river bottom. Additional searches were conducted at the lower ends of tributaries and chutes and backwaters. Most live mussels were identified and returned to the river. However, a small number were kept as voucher specimens and all dead shells were brought back to the laboratory for identification.

A total of 355 live and 1,709 dead mussel specimens was collected from 47 sites surveyed (Table 4-14). Of the 16 species found, only eight were represented by living specimens. Abundance and diversity of live or freshly dead specimens was greatest at sites immediately below Gavins Point Dam. Several sites in this region contained relatively large clam beds. The mouth of the James River had the highest diversity when counting older dead specimens with weathered shells, which likely washed downstream from the James River.

Pink papershell, fragile papershell, and giant floater were the most numerous species collected. No federal or state-listed species were collected during the survey, but two live specimens of flat floater, which has an MONHP ranking of S2 (MDC 2018), were found.

Table 4-14 Number of Freshwater Mussels Collected During Surveys Conducted During 1999 Within the Gavins Point Reach of the Missouri National Recreational River, RM 810-RM 750.2.

Common Name	Live	Dead
Threeridge	0	1
Flat floater	2	0
Rock-pocketbook	0	2
Fatmucket	0	3
Yellow sandshell	0	4
White heelsplitter	33	11
Fragile papershell	96	1,258
Pink heelsplitter	40	72
Pink papershell	130	195
Giant floater	45	116
Stout floater	0	1
Mapleleaf	2	4
Creeper	0	3
Lilliput	0	1
Fawnsfoot	0	1
Deertoe	7	37
Total unionids	**355**	**1,709**
No. of species	**8**	**15**

Source: Perkins and Backlund (2000).

4.5.1.3 Biological Monitoring Program in the Vicinity of the LEC

The 2017-2018 biological monitoring program for the LEC (ASA 2019) included a biological collection program for benthic macroinvertebrates and shellfish conducted quarterly within each of the four zones sampled during fish surveys (Figure 4-2): an upstream control zone (Zone 1), the discharge canal (Zone 2), a thermally exposed zone covering the area of potential thermal plume influence (Zone 3), and a downstream zone beyond the expected influence of the LEC thermal plume (Zone 4). Within each zone, depositional habitats were sampled using a standard Ponar grab sampler whereas rock/gravel substrate habitats were sampled using a Hester-Dendy (H-D) artificial substrate sampler. Qualitative visual searches for native mussels and mussel shells were also conducted at each sampling site to determine the presence of any threatened or endangered species. Results from two years of sampling are discussed herein.

In 2017, a total of 142 out of a planned 160 H-D samples and all of the Ponar samples were collected. The missing eighteen samples were not retrieved due to the samplers being washed away and unrecoverable due to high river flows. In 2018, a total of 156 out of a planned 160 H-D samples and all of the Ponar samples were collected. The missing four samples were not retrieved due to the samplers being washed away and unrecoverable due to high river flows. The only bivalves collected in samples included invasive zebra mussels (*Dreissena polymorpha*) and Asian clams (*Corbicula fluminea*) (ASA 2019). Also present were freshwater snails identified to the *Physa* genus in the Physidae family and the *Ferrissia* genus in the Planorbidae family (ASA 2019). Similar shellfish assemblages were observed during historical sampling conducted in the vicinity of the LEC (EEHI 1976b, UEC 1981).

No live shellfish were observed or collected during three visual surveys conducted near the LEC on 15 September and 7 December 2017 and 1 June 2018 (Table 4-15). Among the dead shells observed were those of fragile papershell, pink heelsplitter, and giant floater, which were among the most common species collected during past surveys conducted in the LMOR (Perkins and Backlund 2000, Hoke 2009). Additional shells that were observed near the LEC were comprised of species known to occur in the LMOR.

No T&E shellfish species were observed in the Ponar samples or during the visual surveys.

Table 4-15 Relative Abundance of Mussels Observed During Visual Search Conducted During 2017-2018 in the Vicinity of the LEC.

		Zone 1			Zone 2			Zone 3			Zone 4		
Common Name	Scientific Name	Sep-17	17-Dec	Jun-18	Sep-17	17-Dec	Jun-18	Sep-17	17-Dec	Jun-18	Sep-17	17-Dec	Jun-18
Asian Clam	*Corbicula fluminea*	A, C	A	A, C	A		R	A, C	A, C	A, C	C, U	A, C	A, C
Zebra Mussel	*Dreissena polymorpha*		A	C, U				R	U	C, U		U	U, R
Fragile papershell	*Leptodea fragilis*	U	C					U, R	C	U, R		U	
Threehorn Warty back	*Obliquaria reflexa*		U							R			
Round pigtoe	*Pleurobema coccineum*							R					
Mapleleaf	*Quadrula quadrula*										R		
	Lampsilis sp.		U										
Pink heelsplitter	*Potamilus alatus*	U								R	U		R
Giant Floater	*Pyganodon grandis*		U	R						U			U

Relative abundance codes: A – Abundant, C – Common, U – Uncommon, R – Rare.

Habitat type codes: OLD – Outside Bend L-Dike, CXLD – Channel Cross-Over L-Dike, CXLDB – Channel Cross-Over L-Dike Bar, IWD – Inside bend W-Dike (refer to ASA 2018 for further description of habitat types).

Note: No live specimens were encountered. Taxa and relative abundances were based off of observed shells.

4.5.2 Summary of Shellfish Community Composition

A total of 20 species (Table 4-16) were identified in surveys conducted along the entire length of the channelized portion of the LMOR as well as the reach immediately below Gavins Point Dam (Perkins and Backlund 2000, Hoke 2009). Pink papershell, fragile papershell, and giant floater were the most numerous species found during both surveys. All three species are considered to be tolerant of water with high silt content. Shells of these species were also detected in the vicinity of the LEC during visual searches. All additional species detected as shells near the LEC were known to occur in the LMOR based on the Perkins and Backlund (2000) and Hoke (2009) surveys.

Searching the Illinois Natural History Survey (INHS) Prairie Research Institute's Mollusk Collection (INHS 2018) database yielded an additional 14 freshwater mussel species known to occur in Franklin County, Missouri. However, none of the 53 INHS specimens collected between 1972 and 2015 were identified as coming from the Missouri River. Instead, specimens were collected either from the Bourbeuse (n=24) or Meramec (n=18) rivers or locality information was withheld (n=11) to protect species of conservation concern (INHS 2018). Thus, it is not known which, if any, of these additional species may be found in the LMOR.

Results from Hoke (2009) may be representative of the species that might occur near the LEC as sampling included segments of the river in close proximity to the facility. All 14 native species identified during the survey were present in the lowermost regions near the LEC. Mussels were almost entirely absent from areas with strong currents and pools behind wing dams were the most common habitats where specimens were found. River currents near the LEC are swift with velocities estimated between 2.6 and 4.8 feet per second (fps) and wing dams do not occur in the immediate vicinity of the CWIS. Thus, the area of the LMOR near the LEC is not expected to provide large areas of suitable habitat capable of supporting high densities of freshwater mussel populations.

One recently dead specimen of the federal and state-listed endangered scaleshell (MONHP ranking S1) was the only listed species collected during river surveys in the LMOR (Hoke 2009). Flat floater and hickorynut, which have MONHP rankings of S2 and S3 (MDC 2018), respectively, were also collected during river surveys. Additional species of conservation concern present in Franklin County, Missouri (Table 4-16) have not been reported to occur in the LMOR.

Freshwater mussels require fish to serve as hosts to parasitic larvae known as glochidia, which encyst onto the gills, fins, or skin of fish until later emerging as juveniles and falling to the substrate to complete their life cycle. Mussels require a specific one or several host species and much information about glochidia-host relationships remains unknown (Tiemann et al. 2011). Known hosts are reported for mussel species listed in Table 4-16 based on records of natural infestations found using the INHS and Ohio State University Museum of Biological Diversity's Freshwater Mussel Host Database (2017).

The only bivalves present in Ponar and Hester-Dendy (H-D) samples collected during the 2017-2018 biological monitoring program included invasive zebra mussels (*Dreissena polymorpha*) and Asian clams (*Corbicula fluminea*) (ASA 2019). Gastropods collected included freshwater snails identified to the *Physa* genus in the Physidae family and the *Ferrissia* genus in the Planorbidae family (ASA 2019).

No live shellfish were observed or collected during three visual surveys conducted near the LEC. In addition, no T&E shellfish species were observed in Ponar samples or during visual surveys conducted during the 2017-2018 biological monitoring program.

Table 4-16 Freshwater Mussel Species Identified in INHS Collections from Franklin County, Missouri (1972-2015) and Surveys (1982-2000) Conducted in the LMOR and Conservation Status and Known Glochidia Host Fish Species.

Scientific Name	Common Name	Franklin County, MO INHS Collections	LMOR RM 810.0 – RM 750.2	LMOR RM 750.2 – RM 0.0	LMOR LEC Vicinity	Conservation Status	Known Glochidia Hosts (Reference)
Actinonaias ligamentina	Mucket	X					American eel (4) Bluegill (23, 4) Green sunfish (23, 4) Largemouth bass (23, 4) Sauger (15) Smallmouth bass (4, 12) Tadpole madtom (4) White bass (19, 23) White crappie (23, 4) Yellow perch (4)
Amblema plicata	Threeridge	X	X				--
Arcidens confragosus	Rock pocketbook		X			MONHP-S3	American eel (23) Freshwater drum (23) Gizzard shad (19, 23) Rock bass (19, 23) White crappie (19, 23)
Ellipsaria lineolata	Butterfly	X					Freshwater drum (10, 23, 4, 12) Green sunfish (19, 23, 4) Sauger (19)
Elliptio dilatata	Spike	X					Black crappie (10) Flathead catfish (10) Gizzard shad (23) Sauger (10) White crappie (10, 23)
Epioblasma triquetra	Snuffbox	X				Fed-Endangered, MO-Endangered, MONHP-S1	Logperch (21)
Fusconaia flava	Wabash pigtoe	X					Black crappie (19, 23, 4) White crappie (23, 4)
Lampsilis cardium	Plain pocketbook	X					Sauger (23, 4) White crappie (23, 4)
Lampsilis siliquoidea	Fatmucket	X	X				Black crappie (20) Bluegill (6, 4, 20) Largemouth bass (20) Pumpkinseed (20)

Scientific Name	Common Name	Franklin County, MO	LMOR			Conservation Status	Known Glochidia Hosts (Reference)
		INHS Collections	RM 810.0 – RM 750.2	RM 750.2 – RM 0.0	LEC Vicinity		
							Tadpole madtom (4) Walleye (4, 20) Warmouth (20) White crappie (20) Yellow perch (4, 15)
Lampsilis teres	Yellow sandshell	X	X	X			Alligator gar (10, 23) Black crappie (19, 4) Green sunfish (19, 4) Largemouth bass (23, 4) Longnose gar (10, 23, 4) Orangespotted sunfish (19, 4) Shortnose gar (23) Shovelnose sturgeon (19, 23) Warmouth (23) White crappie (19, 23, 4)
Lasmigona complanata	White heelsplitter		X	X			Gizzard shad (22) Longnose gar (22) River redhorse (22) Sauger (22)
Leptodea fragilis	Fragile papershell	X	X	X	X		Freshwater drum (9, 23, 12, 5)
Leptodea leptodon	Scaleshell	X		X		Federal-Endangered, MO-Endangered, MONHP-S1	--
Ligumia recta	Black sandshell	X				MONHP-S2	American eel (4) Bluegill (19, 23, 4) Sauger (15) White crappie (23, 4)
Ligumia subrostrata	Pondmussel	X					Bluegill (18) Orangespotted sunfish (13) Warmouth (6)
Obliquaria reflexa	Threehorn wartyback	X		X	X		Goldeye (3) Skipjack herring (4, 23)
Obovaria olivaria	Hickorynut			X		MONHP-S3	Shovelnose sturgeon (4, 10)
Plethobasus cyphyus	Sheepnose	X				Federal-Endangered, MO-Endangered, MONHP-S2	Sauger (19, 23)
Pleurobema sintoxia	Round pigtoe	X			X		Bluegill (4, 19)
Potamilus alatus	Pink heelsplitter	X	X	X	X		Freshwater drum (5, 9, 22, 23)

Scientific Name	Common Name	Franklin County, MO	LMOR			Conservation Status	Known Glochidia Hosts (Reference)
		INHS Collections	RM 810.0 – RM 750.2	RM 750.2 – RM 0.0	LEC Vicinity		
Potamilus ohiensis	Pink papershell		X	X	X		Freshwater drum (5, 9, 22, 23) White crappie (23)
Pyganodon grandis	Giant floater		X	X	X		Allegheny Pearl Dace (20) Black crappie (20, 23) Blackchin shiner (20) Blacknose shiner (20) Bluegill (13, 20, 23) Bluntnose minnow (20) Brook silverside (20) Central stoneroller (20) Common carp (13) Common shiner (20) Freshwater drum (23) Green sunfish (23) Iowa darter (20) Johnny darter (20) Largemouth bass (23) Rainbow darter (20) Roach (13) Rock bass (13) Skipjack herring (23) Striped shiner (20) Yellow bullhead (23) Yellow perch (20) White bass (23) White crappie (13, 23)
Pyganodon grandis corpulenta	Stout floater		X				--
Quadrula metanevra	Monkeyface	X					--
Quadrula pustulosa	Pimpleback	X					--
Quadrula quadrula	Mapleleaf		X	X	X		Flathead catfish (12) Yellow bullhead (19)
Strophitus undulatus	Creeper	X	X				Common shiner (8) Creek chub (8)
Toxolasma parvus	Lilliput		X	X			Bluegill (18) Warmouth (18, 23)
Tritogonia verrucosa	Pistolgrip	X					Mud darter (14) Weed shiner (14) Western mosquitofish (14)

Scientific Name	Common Name	Franklin County, MO INHS Collections	LMOR RM 810.0 – RM 750.2	LMOR RM 750.2 – RM 0.0	LMOR LEC Vicinity	Conservation Status	Known Glochidia Hosts (Reference)
Truncilla donaciformis	Fawnsfoot	X	X	X			Freshwater drum (9, 19, 10, 23) Sauger (19, 23)
Truncilla truncata	Deertoe	X	X				Freshwater drum (23, 14) Sauger (19, 23)
Utterbackia imbecillis	Paper pondshell			X			Bluegill (18) Dollar sunfish (18) Warmouth (18) Western mosquitofish (18)
Utterbackiana suborbiculata	Flat floater		X	X		MONHP-S2	--
Venustaconcha ellipsiformis	Ellipse	X					Blackside darter (1) Cardinal darter (16) Fantail darter (1) Greenside darter (16) Johnny darter (1) Orangethroat darter (16) Rainbow darter (16, 1) Redfin darter (16) Yoke darter (16)
	No. of species	**24**	**16**	**14**	**7**		

Sources: Perkins and Backlund (2000), Hoke (2009), Freshwater Mussel Host Database (2017), ASA 2018, INHS (2018).

Dashes (--) indicate no host species information was available using the Freshwater Mussel Host Database (2017).

References: [1]Allen et al. 2007, [2]Baird 2000, [3]Barnhart and Baird 2000, [4]Coker et al. 1921, [5]Cummings and Mayer 1993, [6]Evermann and Clark 1920, [7]Hove et al. 2015, [8]Hove et al. 2016, [9]Howard 1913, [10]Howard 1914, [11]Howard 1917, [12]Howard and Anson 1922, [13]Lefevre and Curtis 1912, [14]Marshall 2014, [15]Pearse 1924, [16]Riusech and Barnhart 2000, [17]Sietman et al. 2017, [18]Stern and Felder 1978, [19]Surber 1913, [20]Turgeon 1981, [21]Van Susteren et al. 2015, [22]Weiss and Layzer 1995, [23]Wilson 1916, [24]Wilson and Ronald 1967

4.6 RELEVANT TAXA SUSCEPTIBILITY TO IMPINGEMENT AND ENTRAINMENT

A subset of relevant taxa was selected based on relative abundance within sections of the LMOR near and in the vicinity of the LEC, importance to recreational and commercial fisheries, ecological importance, listing as a protected species, or identification as a fragile species as defined at 40 CFR 125.92(m). This section lists the relevant taxa within each of these categories and assesses their susceptibility to impingement and entrainment at the LEC CWIS based on site specific sampling.

4.6.1 Relevant Taxa

4.6.1.1 Species of Relative Abundance

Species of relative abundance were determined by combining the most recent collections made in Segment 14 of the PSPAP during 2015 (Herman and Wrasse 2016) with catches made during the 2017-2018 biological monitoring conducted in the vicinity of the LEC (ASA 2019). Those relevant species categorized as abundant within the river in proximity to the LEC included at least 500 individuals collected across the two survey programs, which was comprised of 15 taxa representing seven families (Table 4-17). Red shiner, shovelnose sturgeon, gizzard shad, channel shiner, and blue catfish collectively represented a majority of the fish in the combined dataset.

4.6.1.2 Fishing Significance

The LMOR is known to provide good recreational fishing opportunities, particularly for species of catfish (blue, channel, and flathead). Freshwater drum, white bass, hybrid striped bass × white bass, and shovelnose sturgeon also commonly are sought and other sport fishes occur in this section of the river (MDC 2017). Furthermore, commercial fishing has been conducted within the Missouri portion of the Missouri River for decades. Restrictions implemented in recent decades have banned the taking of game fish, including catfishes (blue, channel and flathead), paddlefish, and shovelnose sturgeon (MCSR 2018) and the number of commercial fishers and total harvests has decreased in the Missouri River and other commercially-fished waters in the state during recent years (Figure 4-14; Tripp et al. 2012). Buffalos, common carp, and Asian carps currently comprise the majority of the Missouri River commercial harvest, but other fishes, including suckers, carpsuckers, gars, and bullheads, are taken as well (Tripp et al. 2012). Of the taxa fished either recreationally or commercially within the LMOR, 35 were collected during recent sampling in Segment 14 of the PSPAP or in the vicinity of the LEC (Table 4-17). Seven species were categorized as relatively abundant. Eleven taxa, including bigmouth buffalo, quillback, bighead carp, walleye, black bullhead (*Ameiurus melas*), golden redhorse (*Moxostoma erythrurum*), hybrid sauger × walleye (saugeye), spotted sucker (*Minytrema melanops*), striped bass, warmouth (*Lepomis gulosus*), and yellow bullhead (*Ameiurus natalis*), were collected in low abundance (fewer than 10 fish).

4.6.1.3 Ecological Importance

Those species of ecological importance within the LMOR include forage and indicator species. Gizzard shad, shiner, chub, and minnow species, and other forage species provide an abundant food source for sport fishes found in the LMOR near the LEC (Table 4-17). Smallmouth buffalo, shorthead redhorse, and mooneye (*Hiodon tergisus*) have ecological importance as their presence is an indicator of a healthy river system because of intolerance to high turbidity, siltation, and pollution (Becker 1983; ODNR 2017).

4.6.1.4 Mussel Host Species

A number of fish species abundant within the LMOR are known to be host species for freshwater mussel glochidia, which encyst onto the gills, fins, or skin of the host then emerge from the cysts, falling to the substrate in order to complete their life cycle (Tiemann et al. 2011). Some mussel species can utilize a variety of fish species as their hosts, whereas other species are host-specific and only utilize a single species of fish (Tiemann et al. 2011). Fishes that were collected during recent sampling in the LMOR in proximity of the LEC and are known to host glochidia of freshwater mussels that occur in LMOR (Table 4-16) were considered to be relevant species of importance (Table 4-17).

4.6.1.5 Threatened, Endangered, and Protected Species

Two federal-listed species were collected during recent fish surveys of the LMOR (Table 4-17), including the endangered pallid sturgeon (USFWS 2015) and the shovelnose sturgeon, which is listed as a threatened species due to its similarity in appearance to pallid sturgeon (USFWS 2010). Pallid sturgeon, which is also a Missouri-listed endangered (MONHP ranking S1) species, was only collected during sampling for the PSPAP, which was designed to estimate the population size, structure, and distribution of the species. One possible pallid sturgeon specimen was collected during the 2017-2018 biological monitoring program but could not be positively identified. As a result, the identification of this specimen remained as an unidentified river sturgeon (*Scaphirhynchus* sp.). The relative abundance of pallid sturgeon in the LMOR has not markedly increased (Wildhaber et al. 2016) despite more than two decades of stocking efforts (USFWS 2014b) and none has been definitively identified during any recent or past collections made in the vicinity of the LEC or at the CWIS intake or in the discharge canal. The shovelnose sturgeon is numerous in the river and it continues to be fished recreationally.

The Missouri state-listed endangered (S1) lake sturgeon was also collected in low abundance (n=5) during PSPAP sampling and three were collected near the LEC during recent 2017-2018 biological monitoring (Table 4-17). Lake sturgeon have been caught at the LEC on one previous occasion in 2005, when nine were collected at the CWIS in one 24-hour impingement sample and it was later determined that all were tagged, hatchery-reared fish recently stocked in the river at a nearby location. The flathead chub, another Missouri state-listed endangered (S1) species, was collected in low abundance (n=4) in segments of the LMOR near the LEC during past sampling (1996-1998) conducted for the BFS, but it was not collected during recent surveys. The species occurred at highest density in upstream reaches of the river above the Garrison Dam (Berry et al. 2004).

Additional species of state concern according to the MONHP ranking system collected during recent sampling were two species assigned an S2 ranking, plains minnow and ghost shiner; one species assigned an S3 ranking, sturgeon chub; and two species assigned an SU ranking, skipjack herring and American eel (Table 4-17). Highfin carpsucker (S2) and river darter (S3) have been collected during past surveys.

One dead specimen of the federal and state-listed endangered scaleshell (MONHP ranking S1) was the only listed freshwater mussel species collected during river surveys in the LMOR (Hoke 2009). Flat floater and hickorynut, which have MONHP rankings of S2 and S3 (MDC 2018), respectively, were collected during river surveys (Perkins and Backlund 2000, Hoke 2009). Additional species of conservation concern present in Franklin County, Missouri (Table 4-16) have not been reported to occur in the LMOR. In addition, no T&E shellfish species were observed in

Ponar samples or during visual surveys conducted near the LEC during the 2017-2018 biological monitoring program.

4.6.1.6 Fragile Species

Fragile species are defined by the USEPA at 40 CFR § 125.92(m) as follows:

> *Fragile species means those species of fish and shellfish that are least likely to survive any form of impingement. For purposes of this subpart, fragile species are defined as those with an impingement survival rate of less than 30 percent, including but not limited to alewife, American shad, Atlantic herring, Atlantic long-finned squid, Atlantic menhaden, bay anchovy, blueback herring, bluefish, butterfish, gizzard shad, grey snapper, hickory shad, menhaden, rainbow smelt, round herring, and silver anchovy.*

Gizzard shad is the only species listed in 40 CFR § 125.92(m) that was collected in the LMOR in proximity to the LEC during recent sampling (Table 4-17). A single rainbow smelt (*Osmerus mordax*) was collected from a reach located over 70 miles upstream of the LEC during BFS sampling conducted in 1997 (Table 4-6). Post-impingement survival data from the LEC CWIS are not available to determine additional fragile species based on the 40 CFR § 125.92(m) criteria of less than 30 percent impingement survival.

Table 4-17 Relevant Fish Taxa, Classification Category and Number Collected During 2015 Sampling Conducted Within Segment 14 of the PSPAP and 2017-2018 Sampling in the Vicinity of the LEC and During 2005-2006 Impingement Monitoring at the LEC CWIS.

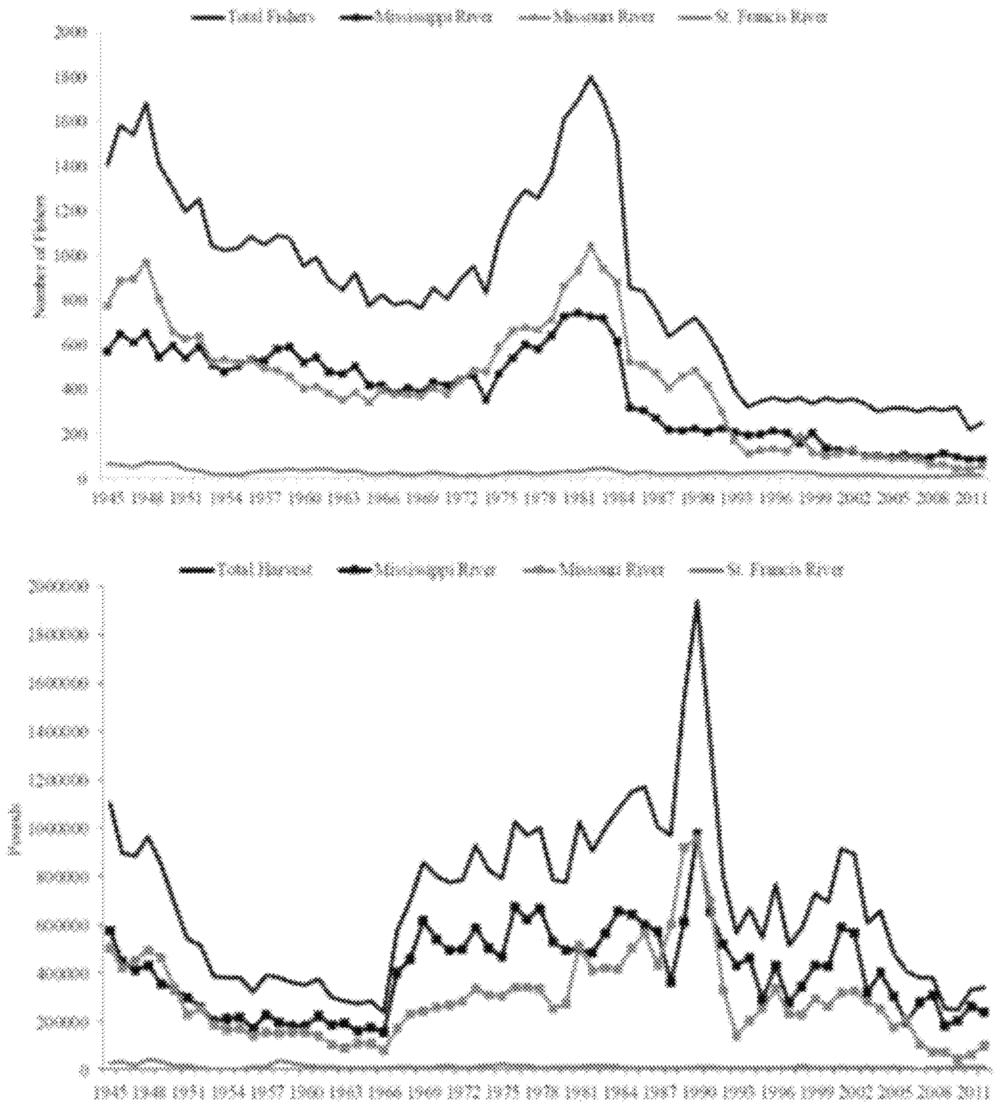
Taxon	Classification	Number Collected	
		Recent Surveys (2015, 2017-2018)	Impingement (2005-2006)
Red shiner	Abundant/Ecological	6,749	4
Shovelnose sturgeon	Abundant/Fishing/Listed: Federal-threatened due to similarity of appearance/Host	3,383	11
Gizzard shad	Abundant/Ecological/Fragile/Host	3,247	4,459
Channel shiner	Abundant/Ecological	3,183	
Blue catfish	Abundant/Fishing	2,836	140
Emerald shiner	Abundant/Ecological	2,195	5
Shoal chub	Abundant/Ecological	1,913	
Sicklefin chub	Abundant/Ecological	1,880	
Channel catfish	Abundant/Fishing	1,880	119
Freshwater drum	Abundant/Fishing/Host	1,817	2,003
Bullhead minnow	Abundant/Ecological	856	1
Unidentified sunfishes (*Lepomis* spp.)	Abundant	853	

Taxon	Classification	Number Collected	
		Recent Surveys (2015, 2017-2018)	Impingement (2005-2006)
Longnose gar	Abundant/Fishing/Host	614	
White crappie	Abundant/Fishing/Host	509	1
Silver carp	Abundant/Fishing	506	5
Orangespotted sunfish	Host	459	
Goldeye	Host	383	28
Bluegill	Fishing/Host	373	28
Blue sucker	Fishing	365	2
River carpsucker	Fishing	359	1
Western mosquitofish	Host	345	
Sand shiner	Ecological	363	
Shortnose gar	Fishing/Host	304	
Smallmouth buffalo	Fishing/Ecological	291	
Common carp	Fishing	213	17
Flathead catfish	Fishing/Host	202	76
Silver chub	Ecological	171	
Bluntnose minnow	Ecological	150	
Sturgeon chub	Listed: Missouri-concern S3	108	1
White bass	Fishing/Host	84	3
Grass carp	Fishing	64	
Green sunfish	Host	44	5
Spotted bass	Fishing	39	
Plains minnow	Listed: Missouri-concern S2	37	
Pallid sturgeon	Listed: Federal-endangered/Missouri-endangered (concern S1)	26 (PSPAP sampling)	
Ghost shiner	Listed: Missouri-concern S2	3	
Black buffalo	Fishing	25	
Paddlefish	Fishing	24	
Striped bass × white bass	Fishing	24	
Shorthead redhorse	Fishing/Ecological/Host	23	5
Sauger	Fishing/Host	21	2
Logperch	Host	16	
Black crappie	Fishing/Host	10	
Largemouth bass	Fishing/Host	10	2
Mooneye	Ecological/Host	10	2

Taxon	Classification	Number Collected	
		Recent Surveys (2015, 2017-2018)	Impingement (2005-2006)
Lake sturgeon	Listed-Missouri-endangered (concern S1)	8	9
Pallid sturgeon × shovelnose sturgeon	Listed: Federal-threatened due to similarity of appearance	7	
Walleye	Fishing/Host	6	
Skipjack herring	Host/Listed: Missouri-concern S3	6	10
Johnny darter	Host	2	
American eel	Host/Listed: Missouri-concern SU	1	
Warmouth	Fishing/Host	1	1
Common shiner	Host	1	
Creek chub	Host	1	
Tadpole madtom	Host	1	

Sources: ASA and Alden (2008), Herman and Wrasse (2016), ASA (2019).

Note: Taxa that were collected in low abundance (fewer than 10 fish) were not considered to provide significant fishing value and are not listed in the table unless they qualified as a relevant taxon under a separate criterion.



Source: Tripp et al. 2012.

Figure 4-14 Total Commercial Fishers (Top Panel) and Harvests (Bottom Panel) in Missouri Waters Including the Missouri River, 1945-2012.

4.6.2 Summary of Relevant Taxa Susceptible to Impingement and Entrainment

The final § 316(b) Rule at § 122.21(r)(4)(iii) requires an assessment of the susceptibility of species and life stages to entrainment and impingement. Impingement is defined at 125.92(n) of the Rule and includes any fish or shellfish that cannot pass through a 3/8-inch square mesh or ¼ X ½ in. mesh screen. Entrainment is defined at § 125.92(h) of the Rule as aquatic organisms that can enter and pass through a CWIS and into the cooling water system. For the purpose of the Rule the definition restricts entrainment to those organisms that will pass through a 3/8-in. square mesh or ¼ X ½ in. mesh screen. For fish, these organisms will be the early life stages for each species, including eggs, larvae, and for some smaller species, early juveniles. The following subsections provide details for those relevant taxa and life stages which are susceptible to impingement and entrainment at the LEC CWIS based on recent and past data collected at the facility.

4.6.2.1 Species Susceptibility to Impingement

Based on 2005-2006 impingement sampling at the LEC, gizzard shad and freshwater drum combined to account for approximately 93 and 81 percent of impinged fish and fish biomass, respectively. Catfishes (blue, channel, and flathead) also collectively represented approximately 5 and 6 percent of impinged fish and fish biomass, respectively. Although not numerically abundant, shovelnose sturgeon (n=11) accounted for 7 percent of impinged biomass (ASA and Alden 2008). Currently, based on data collected between 2015 and 2018 across two survey programs, these species are among the most abundant members of the fish community in the section of the LMOR where the LEC is located (Table 4-17). Thus, gizzard shad and freshwater drum would be expected to be the most susceptible to impingement at the LEC CWIS. However, at least 35 additional taxa were susceptible to impingement during past monitoring programs (Table 4-7).

4.6.2.2 Species Susceptibility to Entrainment

Invasive Asian carp eggs and larvae identified as either bighead carp or silver carp and grass carp, accounted for approximately 85 percent of all fish collected during an entrainment characterization study conducted at the LEC discharge during 2015 and 2016. After excluding these taxa, approximately 98 percent of all remaining entrainment was comprised of fishes identified as minnows, as well as common carp, freshwater drum, gizzard shad and other herrings, carpsuckers and buffalos, goldeyes or mooneyes, or unidentified.

The dominance of Asian carp in entrainment samples likely can be attributed to life history traits as they are known to have high fecundity rates with females producing hundreds of thousands of eggs that develop into larvae while drifting in turbulent waters (Wanner and Klumb 2009, George et al. 2017), which may make them particularly susceptible to entrainment at the LEC CWIS. The low numbers of adult Asian carp, relative to entrainment numbers, caught during monitoring efforts in the river near the LEC may indicate that these species have not been effectively sampled or that they are present at higher densities in other habitats in or near the river but distant from the LEC. Gizzard shad and freshwater drum are among the most abundant taxa present in the LMOR near the LEC (Table 4-17), which increases the probability of entrainment of their larvae. The pelagic egg of freshwater drum, a broadcast spawner like Asian carp, is also susceptible to entrainment. Entrainment of remaining taxa likely was associated with their distribution and abundance near the LEC as a high diversity of minnows occur in the LMOR (Table 4-12), and river carpsucker, smallmouth buffalo, and goldeye have been collected in high numbers during past monitoring efforts (Table 4-1).

Additional details on the site-specific entrainment sampling conducted at the LEC can be found within the § *122.21(r)(9) Entrainment Characterization Study* submittal.

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